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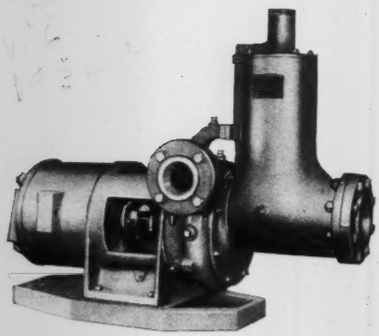

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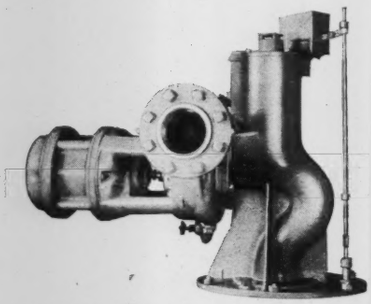

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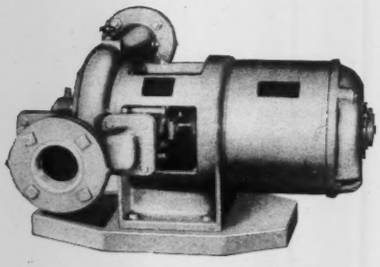

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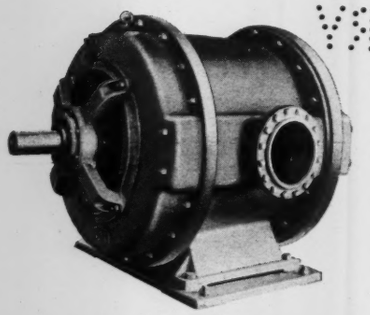

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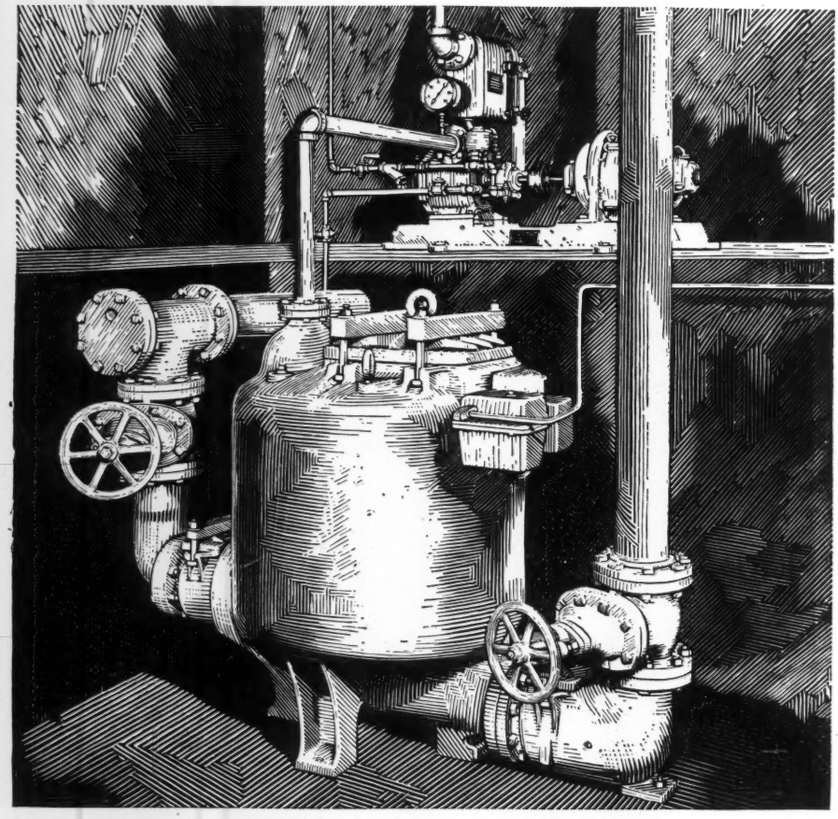

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Heating · Piping
and Air Conditioning
Volume 6, Number 1
January, 1934

The New Code *for* Pressure Piping

[A "Preview" for the readers of HEATING, PIPING AND AIR CONDITIONING]

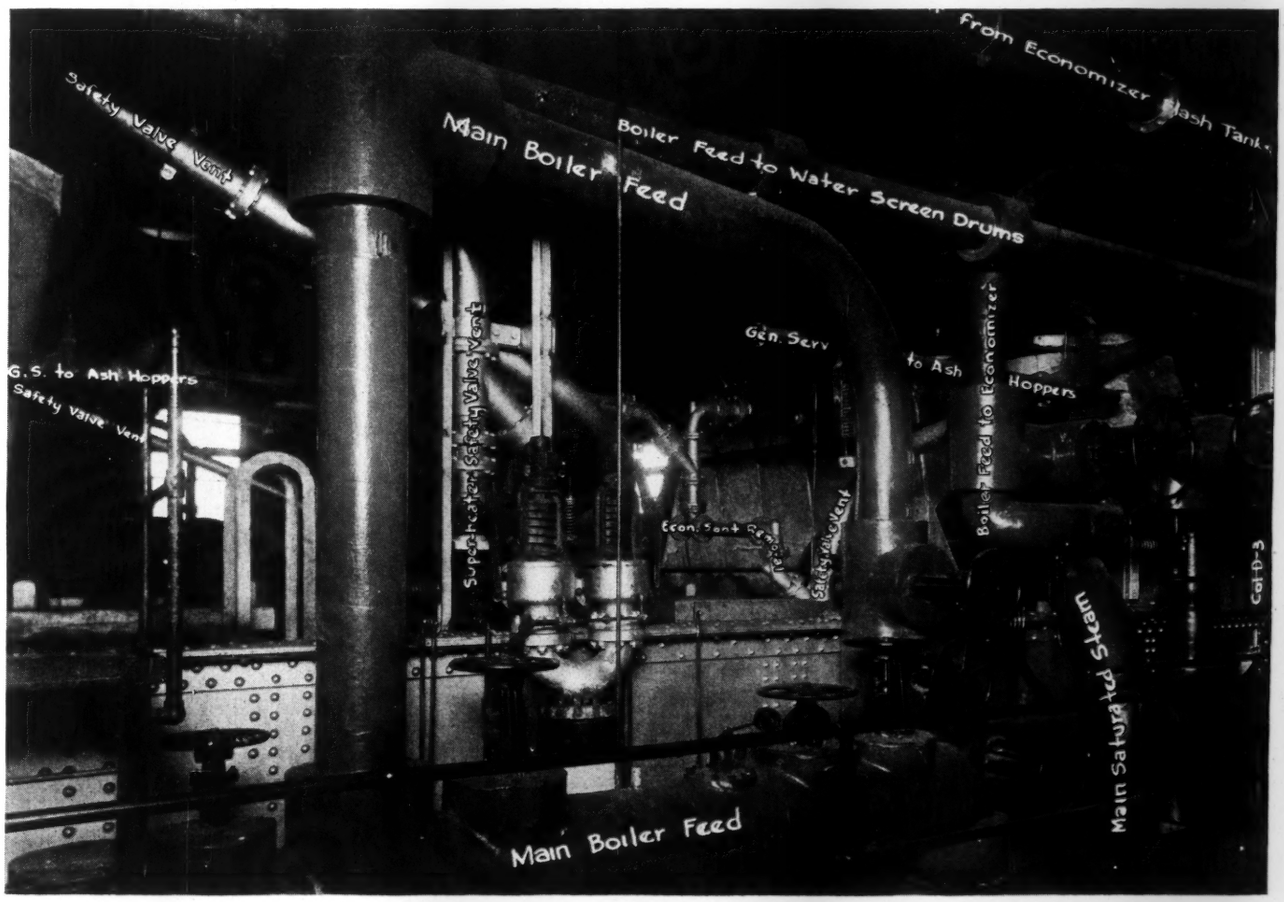
By **Sabin Crocker***

SEVEN years of intensive work by *A. S. A.* Sectional Committee *B31* will be culminated in the near future by publication of the Proposed American Standard Code for Pressure Piping. The Code has been awaited expectantly as a much needed vehicle for setting up and standardizing on a national basis minimum requirements of safe practice for piping. Some explanation of the Code itself and the reasons for setting it up should be of assistance in furthering a general understanding of its scope and purpose.

*Engineer, The Detroit Edison Company, and Member of Board of Consulting and Contributing Editors. Among other standardization committee affiliations, Mr. Crocker is Chairman of Subcommittee *1* on Plan, Scope, and Editing of *A. S. A.* Sectional Committee *B31* on Code for Pressure Piping.

This article continues the series on piping standardization, which started in the September, 1933, H. P. & A. C.

The decorative illustrations accompanying this article are typical views of the sort of piping covered by the Code



THIS PREVIEW of the Proposed American Standard Code for Pressure Piping will give the readers of HEATING, PIPING AND AIR CONDITIONING a general idea of the nature of the Code to be published early this year by the American Standards Association. The Code for Pressure Piping, which is intended to serve much the same purpose in its field as the A. S. M. E. Boiler Construction Code does in another, sets minimum safety requirements for the design, manufacture, fabrication, erection and test of piping systems and their parts. If favorably received by government and industry, it undoubtedly will become part of the safety regulations of many states and cities.

Need and Inception of Code

The Sectional Committee on Code for Pressure Piping was organized on November 12, 1926, under the procedure of the *American Standards Association* and the sponsorship of *The American Society of Mechanical Engineers.* The project had its inception through a series of events which ultimately pointed to the necessity for having a national safety code for pressure piping.

In 1914 the *A. S. M. E.* adopted and published the first edition of its Boiler Construction Code which embraces rather extensive safety rules pertaining to piping immediately connected to the boiler. In June, 1915, the *Power Piping Society,* a trade association of piping fabricators and erectors, adopted and published its first Standard Specifications for Power Piping, which have been amplified and revised from time to time since. During the early 1920's numerous discussions at meetings of *A. S. A.* Sectional Committee *B16* on Pipe Flanges and Fittings brought out the need for a general safety code for pressure piping which would correlate the design, installation, and test of piping systems with suitable dimensional standards and materials specifications. Prior to 1924 the *Industrial Commission* of the State of Ohio and the *Ohio Society of Safety Engineers* embarked on a program for drafting a safety code for pressure piping for the State of Ohio.

These and similar events pointed to the desirability of developing such a safety code on a national scale and making sure that all interests concerned had a hand in its formulation. The disastrous results of leaving so technical a task to safety bodies in the several states and numerous municipalities was at once apparent since the various components of any piping system, such as pipe, fittings, valves, bolting and the like, are articles of inter-state commerce. Practically every manufacturer of these commodities ships his product to all parts of the nation. Imagine the confusion which would result if a given article were accepted for say 400-lb steam service pressure in one state, 500-lb in a second, and only 300-lb in a third! Systematic marking would be out of the question, a great deal of unnecessary duplication would be created, and the problem of stocking materials for quick shipment would be vastly complicated if not rendered impossible. Furthermore it would be impracticable to give the requisite time and expert attention to the development of rational codes in such multiplicity, and as a result these codes could not be worked out on the sound engineering basis possible with a national code.

Organization of the Committee

The question of setting up a national piping code was brought before the Council of the *A. S. M. E.* in 1925, with the recommendation that the Society accept responsibility for this undertaking and start the necessary action leading to the organization of a sectional committee under *A. S. A.* procedure. As is customary, an informal conference was held in May, 1925, during the spring meeting of the *A. S. M. E.;* this conference agreed that the project should go forward, but was not able to say what should be its scope. The results of this conference were communicated to the *A. S. M. E.* Standardization Committee and the Council, and a letter suggesting the project was written by the Society to the *A. S. A.* in September, 1925. In March, 1926, the *A. S. A.* extended a formal invitation to the *A. S. M. E.* to accept sole sponsorship, not naming the scope.

The Society accepted this sponsorship immediately, and within a few days invitations went out to 61 national organizations and governmental bureaus requesting them to appoint representatives. Out of this number, 40 organizations felt sufficiently concerned to accept representation through 74 individual memberships on the Sectional Committee, and actually participated in drafting the Code. Among the principal groups represented were: national engineering societies; numerous trade associations; several bureaus of the federal government including those of the navy department and the steamboat inspection service; safety engineers; inspection agencies; insurance underwriters; U. S. Department of Labor; building and ship-owners associations; steel, cast-iron and brass manufacturers; power, oil, gas, and water-supply interests; consulting engineers and independent experts.

On November 12, 1926, an organization meeting of the Sectional Committee on Code for Pressure Piping was called for the purpose of electing officers and familiarizing the membership with the project. A subcommittee on Plan, Scope and Editing was appointed to formulate a statement of the scope of the Code, to recommend an appropriate subdivision of work, and to draft for review and criticism by the main committee a sample section which could serve as a model for other sections. The subcommittee subsequently held two meetings and carried on an extensive interchange of correspondence between members, developing ultimately a comprehensive plan which was presented to the Sectional Committee at a meeting on April 7, 1927. The plan, as modified and adopted by the Sectional Committee at that meeting, has been followed with only minor changes in drafting the Tentative Code for Pressure Piping which will be sent shortly to the members of the Sectional Committee for vote on approval by letter ballot.

Scope of the Code

The purpose of the Code for Pressure Piping is to serve as a standard of minimum safety requirements for: (1) the choice of suitable materials and reference to specifications covering same; (2) the designation of proper dimensional standards and methods of fabrication for the elements comprising piping systems; (3) the listing of suitable formulas and requirements for the design of these elements and their supports; (4) the erection of piping systems; and (5) the testing of the elements before erection, and of the completed systems after erection. The distinction should be drawn that this is primarily a safety code covering minimum requirements, rather than a design code for laying out piping systems for economical operation. Piping systems coming under the code must conform to the minimum requirements listed therein; the use of material and construction having properties superior to the minimum requirements is, of course, permitted.

Piping not considered as constituting a safety hazard is exempted from the scope of the code, such, for instance, as: Building heating systems operating at less than 15-lb gage pressure, plumbing, sprinkler systems, roof and floor drains, sewers, and the like. Among the foregoing, sanitary piping is adequately covered by plumbing codes based on considerations of health rather than pressure hazard. All valves, fittings, and piping for boilers as prescribed in the *A. S. M. E.* Power Boiler Code are considered as part of the boiler installation and hence are outside the scope of the pressure piping code. Economizers, heaters, tanks and other pressure vessels also are outside the scope of this Code, but connecting piping comes under its requirements.

The Code is not intended to be retroactive and should not be construed as applying to piping systems erected before, or under erection at the time of its approval by the *American Standards Association.* The committee desires that this Code be given a fair trial by industry. During this trial period the committee will welcome an opportunity to explain in further detail any of its provisions and will give full consideration to suggestions for changes and additions.

Content and Plan of the Code

The outline set up for the Code called for subdividing it into sections, each dealing with a particular kind of piping and assigned for preparation to a subcommittee of experts in that field. In addition to selection of these subdivisions according to service, provision was made for two sections of a general nature applying to all services, which would deal with available materials specifications and fabrication details. As set up at present, the following sections comprise the Code:

Section 1—Power Piping
Section 2—Gas and Air Piping
Section 3—Oil Piping
Section 4—District Heating Piping
Section 5—Fabrication Details
Section 6—Materials

The original intention was to have sections also on hydraulic piping and refrigeration piping, but the necessary cooperative effort for the first-mentioned section has not materialized as yet. Preparation of a section on refrigeration piping is under consideration and it is expected that this section will be included in the second edition of the Code, if not in the first.

SECTION 1—POWER PIPING

Section I of the Code covers power-piping systems for steam-generating plants, central-heating plants, and industrial plants. Power-piping systems are defined as including all steam, water, and oil piping; and as excluding gas and refrigerating piping, central- and district-heating distribution systems, building-heating piping when the pressure does not exceed 15 psi gage,† roof and floor drains, plumbing, sewers, sprinkler systems, piping for hydraulic pressure tools or equipment, and industrial process piping for fluids not mentioned above. For the convenience of the reader a number of the general paragraphs of the Code are quoted here in their entirety (in smaller type and included within quotation marks to distinguish them from material summarized in the author's own words). Those interested in obtaining preliminary proof copies of the Code for more intensive study should apply to *The American Society of Mechanical Engineers* at 29 West 39th Street, New York, N. Y.

Materials—This section of the Code requires that the physical and chemical properties of the materials shall be in accordance with the following specifications:

"Materials. The materials employed shall be capable of meeting the physical and chemical requirements and tests of the latest revision of the following specifications:

Material	Specification
Cast iron[1] for valves, flanges, and fittings	*A.S.T.M. A* 126
Cast iron[1] pipe, pit cast	*A.W.W.A.*
Cast iron pipe,[1] centrifugally cast or horizontally cast in green sand molds	*F.S.B. WW-P*-421
Cast steel	*A.S.T.M. A* 95
Forged steel	*A.S.T.M. A*-105
Bronze[2] (or brass) for flanges, valves, and fittings	*M.S.S. SP*-20
Malleable iron[3]	*M.S.S. SP* 22
Bolts, alloy steel	*A.S.T.M. A* 96
Bolts, commercial steel	*A.S.T.M. A* 107
Bolts, wrought iron	*A.S.T.M. A* 84
Pipe, steel, up to 250 lb S.S.P.[4] or 500 F	*A.S.T.M. A* 53
Pipe, steel, over 250 lb S.S.P. or 500 F	*A.S.T.M. A* 106
Pipe, seamless brass[5]	*A.S.T.M. B* 43
Pipe, seamless copper[5]	*A.S.T.M. B* 42
Tubes, seamless copper[5]	*A.S.T.M. B* 75
Tubes, seamless copper[5]	*A.S.T.M. B* 88
Pipe, wrought iron[6]	*A.S.T.M. A* 72
Pipe, electric-fusion-welded steel	*A.S.T.M. A*134 and *A* 139
Pipe, electric resistance-welded steel	*A.S.T.M. A* 135
Pipe, forge-welded steel	*A.S.T.M. A* 136
Pipe, riveted-steel and wrought iron pipe	*A.S.T.M. A* 138
Pipe, *Class I* electric-fusion-welded steel	*A.S.T.M. A* ...

[1]Cast iron shall not be used for any service in excess of 450 F and not for oil in excess of 300 F.
[2]Bronze (or brass) (fittings and valves) shall not be used for any service in excess of 500 F.
[3]Malleable iron shall not be used for any service in excess of 500 F.
[4]S. S. P. is abbreviation for steam service pressure.
[5]Brass and copper pipe shall not be used for any service in excess of 406 F.
[6]Wrought-iron pipe shall not be used for any service in excess of 750 F.

"Notes: Specifications referred to above have been developed and published by the following organizations: *American Society for Testing Materials (A. S. T. M.), American Water Works Association (A. W. W. A.), Manufacturers Standardization Society of the Valve and Fittings Industry (M.S.S.),* and *Federal Specifications Board,* U. S. Government *(F. S. B.).*

In all cases the last revision is to be adhered to."

Dimensional Standards for Flanges and Fittings—The dimensional standards for flanges and fittings required for various services coming under this section are American Standards approved by the *American Standards Association.* Specific requirements for a variety of pressures and temperatures are set up under sub-headings for different systems such as steam, boiler-feed, blow-off, instruments, service-water and circulating-water, and oil-piping systems. The last named includes only such oil systems as are incidental to the use of power piping or equipment served by power piping, such as the lubricating systems of turbo-generators. Special fittings having overall dimensions differing from the regular shapes must be designed to withstand the standard hydrostatic-test pressures. Minimum metal thicknesses can in no case be less than those specified for the pressures and temperatures in the respective American Standard.

"Valves. (a) It is mandatory that valves be, (1) of the design which the manufacturer thereof recommends for the service, and (2) of the materials allowed by the Code for the pressure and temperature. Body metal thickness shall not be less than that of fittings for corresponding size and rating. Each valve, of a size permitting, shall bear the maker's name or trademark and reference symbols by means of which may be determined the service conditions for which the maker guarantees the same.

"(b) Screw-end valves shall be threaded according to the American Standard for Pipe Threads (*A.S.A. B2*). Flange-end valves shall have connecting-end flanges according to the American flange standard for the maximum pressure and service for which the valve is designated.

"(c) All stop valves for steam and for water lines with fluid at temperature in excess of 212 F shall have their bonnets backseated to provide for repacking under pressure."

"Reducing and Relief Valves. (a) Where pressure-reducing valves are used, one or more relief or safety valves shall be provided on the low-pressure side of the reducing valve in case the piping or equipment on the low-pressure side does not meet the requirements for the full initial pressure. The combined discharge capacity of the relief valves shall be such that the pressure rating of the lower pressure piping and equipment shall not be exceeded in case the reducing valve sticks open.

"(b) An exception may be made in a steam plant used for district heating and where there are always attendants on duty, by installing a suitable audible alarm actuated by steam pressure. It then shall not be mandatory to install a safety valve on the low-pressure side of the piping.

"(c) The use of hand-controlled bypasses around reducing valves is permissible. Reducing valve bypass, if used, shall not be greater in capacity than the reducing valve, unless the piping is adequately protected by relief valves.

"(d) The flange dimensions, wall thickness and material of reducing and relief valves shall conform to the requirements specified herein for valves and fittings for the pressures and temperatures to which they may be subjected.

"(e) It is mandatory that a pressure gage be installed on the low-pressure side of a reducing valve.

"(f) Exhaust and pump-suction lines for any service and pressure shall be provided with relief valves of suitable size unless said lines and attached equipment are designed for the

†All pressures referred to in the Code, unless otherwise stated, are understood to be lb per sq inch gage.

maximum pressure to which such lines may accidentally or otherwise be subjected, or unless a suitable alarm indicator, such as a whistle or free blowing relief valve is installed where noticeable to the operator of such equipment."

"Bolting. (a) Bolts and nuts shall be of the dimensions and material specified for the purpose in the corresponding American flange standards. Bolts shall extend completely through the nuts. The bolting material shall conform to the *A.S.T.M.* Specification *A96* for steam service pressure in excess of 250 lb per sq in., or steam or water temperatures over 450 F.

"(b) Bolt heads and nuts shall be semi-finished in accordance with the "Heavy Series" of American Standard for Wrench-Head Bolts and Nuts (*B18.2*).

"(c) Washers, when used under nuts, shall be of forged or rolled carbon steel.

"(d) For service where *A.S.T.M.* Specification *A96* is not mandatory, commercial steel bolts (*A.S.T.M. A107*) or wrought iron bolts (*A.S.T.M. A84*) shall be used in accordance with the specific requirements of this Section.

"Pipe Threads. All pipe threads on pipe, valves, fittings, etc., shall conform to the American Standard for Pipe Threads (*B2*)."

"Pipe Joints. Flanges shall be attached to the pipe by threading (except where prohibited under the specific requirements of this Section), by lapping (commonly known as van stoning), by welding in compliance with the requirements of Section 5, Chapter 3 of this Code, or by other approved methods. If screwed unions are used, their body material shall be that allowed for use in valves, fittings, or pipe for the specified service."

"Gaskets. (a) Where gaskets are required, gasket material shall be used which is not attacked detrimentally by the fluid carried in the pipe line; it shall have sufficient strength to hold the pressure to which it is subjected and it shall maintain its physical and chemical properties so as to perform the purpose intended throughout the temperature range encountered. Gaskets shall be as thin as the finish or surface will permit to reduce probability of blowing out.

"(b) For all lines under pressure and above 250 F the gaskets shall be metallic, asbestos or other non-burning material. For further details concerning gaskets refer to Section 5, Chapter 2 of this Code."

"Thermal Expansion. (a) Where pipe bends are used for expansion at temperatures not exceeding 750 F, and where the calculated expansion exceeds ¼ in., it is recommended, when practicable, that piping be cut short about 50 per cent of the amount of thermal expansion and cold sprung during erection. See also Section 5, Chapter 4 of this Code.

"(b) Expansion joints of either the slip-sleeve or swivel types may be used provided, however, that (1) the materials used in their construction shall conform to this Code; (2) the design shall provide ample proportions for the structural and working parts thereof; and (3) for pressures in excess of 15 lb per sq in., the design shall embody provision against complete disengagement of the working parts while in service.

"(c) Non-reinforced corrugated copper expansion joints shall not be used for steam pressures exceeding 25 lb per sq in. Corrugated copper expansion joints when reinforced with exterior rings or sleeves may be used for steam pressures not exceeding 200 lb per sq in.

"(d) Nothing in this paragraph shall be construed as limiting the use of expansion joints, corrugated pipe or bends made of the same material as the remainder of the pipe."

"Hangers, Supports, Anchors. (a) Piping and equipment shall be supported in a thoroughly substantial and workmanlike manner, rigid enough to prevent excessive vibration and anchored sufficiently to prevent undue strains on boilers and equipment served. Hangers, supports, and anchors shall be made of non-combustible and durable materials. Wood or wire shall not be used for permanent pipe hangers or supports inside a building of permanent construction or a tunnel.

"(b) Hangers and supports shall be so installed as not to interfere with the free expansion and contraction of the piping between anchors. All piping, shall be carried on adjustable hangers or properly leveled supports, and suitable springs, sway bracing, vibration dampeners, etc., shall be provided where necessary. Pipe hangers, supports, anchors, etc., shall be fabricated in accordance with Section 5, Chapter 1 of this Code."

"Pipe Sleeves. (a) Where steam pipes pass through walls, partitions, floors, beams, etc., constructed of combustible material, a protecting metal sleeve or thimble which gives a clearance of not less than ¼ in. under hot and cold conditions all around the pipe or pipe and covering shall be provided. When steam pipes pass through metal partitions, etc., a clearance of at least ¼ in. under hot and cold conditions shall be left all around the pipe, or pipe and covering. In any case, if the fluid temperature exceeds 250 F, the pipe shall be insulated inside the sleeve with a covering of at least standard thickness.

"(b) In no case shall walls, floors, partitions, beams, etc., be cast on solidly or built up around and in contact with a steam, hot water, or oil pipe. Where it is necessary to install such pipe in a concrete floor or other building member, it shall be protected for the entire length of bury with a suitable protecting pipe sleeve of steel, cast iron, wrought iron, or of tile; exception may be had to the preceding rules in the case of pipes passing through walls, floors, partitions, etc., which must be kept water-tight."

"Drains, Drips, and Steam Traps. (a) Suitable drains or drips shall be provided wherever necessary to drain the water of condensation from all sections of the piping and equipment where it may collect. Suitable drains shall also be provided for emptying water lines, water storage tanks, equipment containing water, etc. at times when such piping and equipment may be out of service. At least one valve shall be placed in each drip or drain line.

"(b) Drip lines from steam headers, mains, separators, and other equipment shall be properly drained with the traps installed in accessible locations and below the level of the apparatus drained, if practicable. Drip pumps, drip tanks, and open discharge drips (preferably with orifice control) may be used in lieu of traps, provided they are safely installed, protected, and operated

10-in. pipe line for gas-burning installation

under constant supervision. All drain lines shall be provided with drip valves for free blow to the atmosphere.

"(c) Drip lines from steam headers, mains, separators, or other equipment operating at different pressures shall not be connected to discharge through the same trap. Where two or more drips discharge into the same trap, a check valve and a stop valve shall be placed in each line. Where several traps discharge into one header under pressure, or which may be under pressure, a stop valve and a check valve shall be placed in the discharge line from each trap.

"(d) The weight of trap discharge piping shall be the same as the inlet piping unless it is vented to atmosphere or operated under low pressure and has no stop valves. The trap discharge piping shall in all cases be of at least the pressure rating of the maximum discharge pressure to which it may be subjected. Trap discharge piping shall be protected against freezing where necessary."

"Inspection and Tests. All material shall be capable of meeting the inspection and test requirements described in the corresponding specification listed in *Par.* 105. Unless otherwise specified by the purchaser, the manufacturer's certification that these tests have been met shall be accepted as satisfactory."

"Cleaning. The inside of all pipes, valves, and fittings shall be smooth, clean, and free from blisters, loose mill scale, and dirt when erected. All lines should be blown before placing in service, if practical."

"Hydrostatic Tests Before Erection. Piping, valves, fittings, etc., shall be capable of withstanding a hydrostatic shell test, made before erection, to twice the basic steam service pressure, except that steel fittings and valves shall be tested to pressures as given in Table 1.

Table 1—Hydrostatic Tests for Steel Fittings and Valves

Basic Steam Service Pressure, Lb per Sq In.	Test Pressure, Lb per Sq In.
150	350
300	750
400	1000
600	1500
900	2000
1500	3500

Note: The term basic steam service pressure shall be interpreted in this Section as the maximum steam pressure for which a given piping system may be used in conformance with the requirements of this Section of the Code. For example, if a service system for 400 lb per sq in. water pressure is designed as for 250 lb per sq in. steam service pressure in accordance with *Par. 156*, the test pressure is 500 lb per sq in."

Specific Requirements

Following the general requirements for power piping abstracted above there are several groups of specific requirements for particular service conditions embracing: (*a*) steam pressures from 250 to 1,500 lb or temperatures from 450 to 750 F; (*b*) steam pressures from 125 to 250 lb, and temperatures not in excess of 450 F; (*c*) steam pressures from 25 to 125 lb, and temperatures not in excess of 450 F; (*d*) steam pressures up to 25 lb and temperatures not in excess of 450 F; (*e*) hot-water systems over 250 F, and boiler-feed systems; (*f*) blow-off piping; (*g*) service-water and condensing-water systems; (*h*) oil-piping systems incidental to power plants; (*i*) instrument piping. These specific requirements cover permissible types of valve construction, end connection, pipe manufacture, qualifications for welders, etc.

[Further articles on the Code for Pressure Piping will cover rules governing the thickness of pipe and *Sections 2* to *6* inclusive, dealing with Gas and Air Piping, Oil Piping, District Heating Piping, Fabrication Details, and Materials Specifications.—EDITOR.]

Heat Loss Through Canvas Partition

CAN you give me some idea of the heat loss through a canvas partition? I have a large room to heat with a large open stairway and a partially-heated room above.—W. A. N.

Answer: From the nature of the question it is assumed that the canvas is to be used as an inside partition, and not as a wall exposed to the weather. In the latter case no calculation of heat loss is possible because the major part would probably consist of air leakage through the canvas, and I know of no data on such leakage.

In the case of an inside partition, the air leakage can probably be disregarded. The thickness of the canvas is so small that it offers practically no resistance to the flow of heat. Hence, the total resistance would be that of the air films on the two sides. Since it is an inside partition, it will have still air on both sides and the overall coefficient of heat transmission U in Btu per sq ft per hr per F difference in temperature from the air on one side to that on the other side will be:

$$U = \frac{1}{\frac{1}{1.34} + \frac{1}{1.34}} = 0.67$$

The total heat loss would then be:

$$H = 0.67\,A\,(t_1 - t_2)$$

in which H = heat loss in Btu per hour, A = area in sq ft, t_1 = temperature of air in the warm room in F, and t_2 = temperature of air in the cold room in F. This latter temperature is approximately the mean between the outdoor temperature and the air in the warm room.—A. P. KRATZ.*

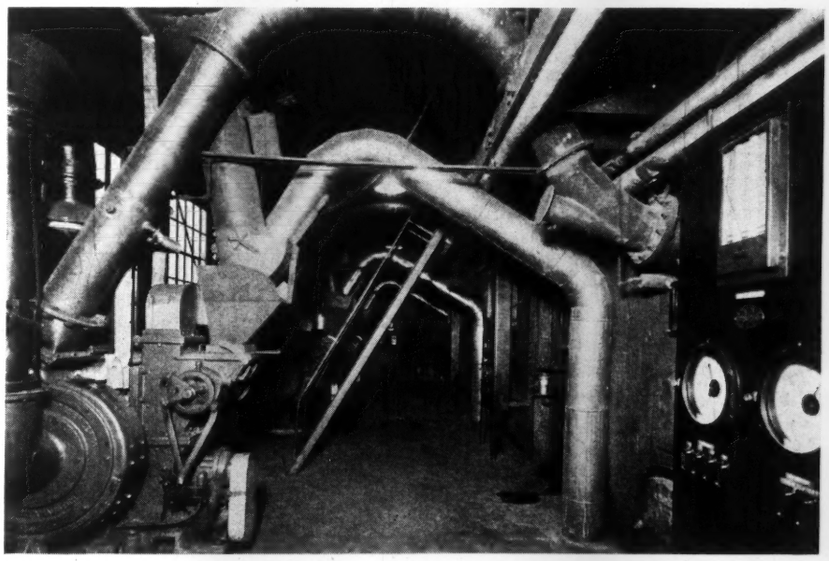
*Research Professor, Department of Mechanical Engineering, University of Illinois, Urbana, Ill.

Bolting Up Joints

When bolting up joints, the tensile stress in the bolt may be increased from 30 per cent to as much as 150 per cent by striking the wrench with a hammer. Striking the far end of the lever arm will not accomplish much; the wrench should be struck as close to the nut as possible to help in overcoming friction. It is the writer's observation that a great many mechanics overlook this fact.—F. W.

PURPOSE of this article (which includes some interesting operating results and costs) is to show that pulverized Illinois coal can be burned efficiently and economically in the Chicago district without fly-ash deposition, and with a reasonable investment cost, using an old, small chimney... Mr. Lewis has been something of a pioneer in encouraging the application of pulverized coal burning to medium-size industrial heating plants.

Operating Results *with a* Pulverized-Coal-Burning Plant



The firing aisle as seen from the Engineer's office

The pulverizers are at the left and the boilers are at the right. The nearest duct crossing the aisle carries the coal and the hot air from the fan to the burner. The second duct crossing the aisle carries hot air from the heated rear wall and furnace floor to the pulverizer.

The controlling and instrument panel for the north boiler is shown in the right foreground.

By **Samuel R. Lewis* and S. I. Rottmayer†**

FIVE years ago a new steam-generating plant was built for heating the buildings and the metal in the unheated buildings at the Chicago warehouses and offices of Jos. T. Ryerson & Son, Inc., iron, steel, and machinery merchants. Publication of the results has been delayed until now, so that the costs could be determined by actual experience.

The buildings consist of offices and warehouses on the greater part of an area of 650,000 sq ft (15 acres). A large restaurant is included. The heating plant is a two-pipe steam system with vacuum pumps, utilizing about 80,000 sq ft equivalent of direct and indirect cast-iron radiation. Steam is transmitted through the plant to several reducing valves at 40-lb pressure in well-insulated steam mains which are run partly overhead through the warehouse trusses, and partly in tunnels.

In the old boiler plant, there were four horizontal Scotch-marine-type boilers each rated at 125 hp. They were hand-fired with No. 3 nut Springfield, Ill., coal of 10,500 Btu per lb burned in dutch-oven settings at the front ends of the furnaces. There was a steam-driven vacuum pump on the returns discharging the condensate

*Consulting Engineer, Chicago, and Member of Board of Consulting and Contributing Editors.
†Of the Staff of Samuel R. Lewis.

into an overhead open receiving tank, which supplied steam-driven, reciprocating boiler-feed pumps.

The new plant was constructed during the summer on the site of the old plant. One of the old boilers temporarily was reset outside of the boiler house, and was connected to the steam main so as to supply the steam to the kitchen and laundry and for heating hot water. The boiler-room floor was excavated to 3 ft below its old level so as to permit the installation of the new equipment under the existing roof trusses.

Pulverized Coal Steam-Generating Plant

The new steam-generating plant includes three 250-hp straight-tube, water-tube, longitudinal-drum boilers designed to burn pulverized coal. The boilers are set with the bottoms of the front and rear tube headers 11′-0″ and 9′-6″, respectively, above the floor. The furnaces are 8′-0″ wide. The rear walls, side walls and floors of the combustion chambers are air cooled.

The outsides of the boiler walls are insulated with 4½ in. of rock wool insulation inside of No. 14 gage air-tight steel jackets. The tops of the boilers have insulation brick, common brick and a hard cement finishing coat.

Primary air is drawn by each pulverizer through the hollow masonry rear wall and the floor of the combustion chamber of the corresponding boiler and is blown with the coal, into the furnace, through a short-flame burner. The front wall of each combustion chamber is of plastic refractory material, concave-shaped to form a reflector behind the burner.

A supply fan for secondary air draws from outside over the duct-encased breeching resulting in a decided temperature gain. This preheated air is discharged into a concrete tunnel behind the boilers, from which tunnel it enters the side walls of each boiler through steel ducts, provided with dampers. The air further is increased in temperature by passing through the heated ducts in the side walls and it finally enters the combustion chamber through a 3 in. by 20 in. slot in each side wall at a point on a level with the center of the burner.

Temperatures of the air at various points, taken during a series of efficiency tests on the boilers at certain ratings, are presented in the following table:

		Primary Air Temperature		Secondary Air Temperature		
Boiler Load, % of Rating	Flue Gas Temp., F	Inlet	Outlet	Outside Air Temp.	Into Secondary Air Tunnel	Into Furnace
80	437	56	248	32	100	475
153	510	66	320	30	118	450

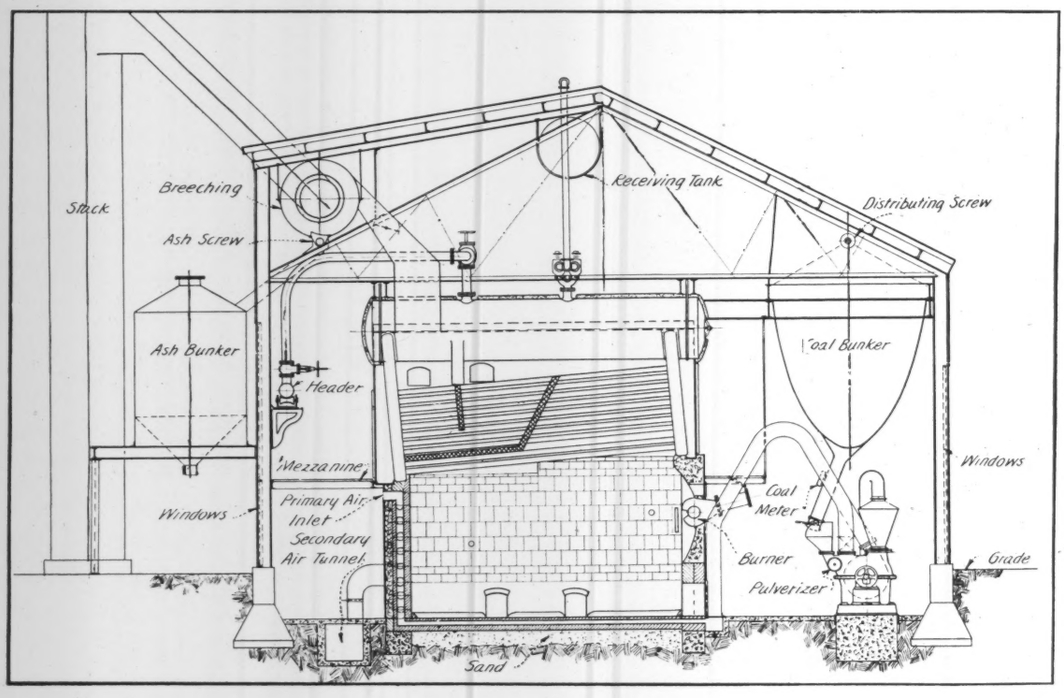
The unit pulverizers are of the impact type, and are driven by individual electric motors. Various kinds of low-grade Illinois coal are burned.

Breeching Designed to Separate Fly Ash

The breeching is especially designed to separate fly ash from the gases by centrifugal force. It is cylindrical

Sectional elevation looking north across the boiler house

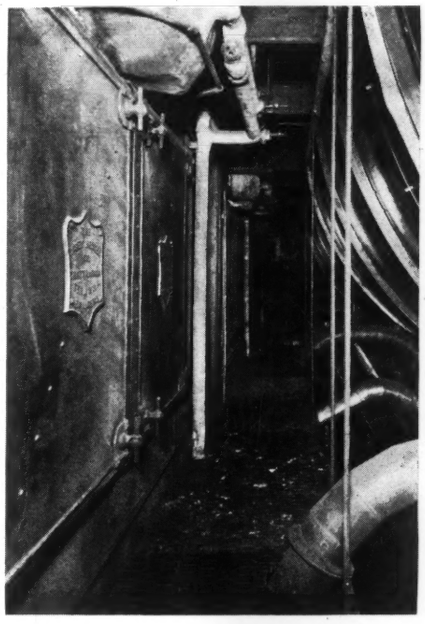
It will be observed that the top cross members of the boilers barely clear the bottoms of the old trusses, and that a new roof above the old trusses protects the breeching, while the coal conveyor and the steam pipes pass through the old trusses. The secondary-air fan takes its supply from out-of-doors, through a jacket around the warm breeching, and delivers this heated air to the tunnel shown behind the boiler, from which it enters the hollow side walls of the setting—not the rear walls, as might be inferred from the drawing



in shape and extends the entire width of the battery of three boilers. The uptakes from each boiler are 8′-0″ wide and only 14 in. high where they enter the breeching and join the breeching at a tangent to its periphery. The uptake gases travel rapidly in a spiral-like course around the inside circumference of the breeching so that the heavier particles of fly ash tend to remain at the outside, with the dust-clear gases in the center, after the manner of a centrifugal dust separator laid on its side.

Midway between each of the boiler smoke intakes to the breeching there is a steel outlet connection from the breeching to the chimney. These outlets each extend into the relatively dust-free central area, and permit the gases to escape from the breeching to the stack from a zone in which the gases are in the least rapid motion and consequently where they carry the least fly-ash.

The fly-ash thus separated collects in the bottom of the breeching where a drag-chain conveyor is located in a trough. Once or twice a day, depending on the amount of coal burned, the conveyor is operated for a few minutes to scrape the fly-ash into a chute which extends into a closed and elevated ash bunker out-of-doors.



Intermediate walkway across fronts of boilers

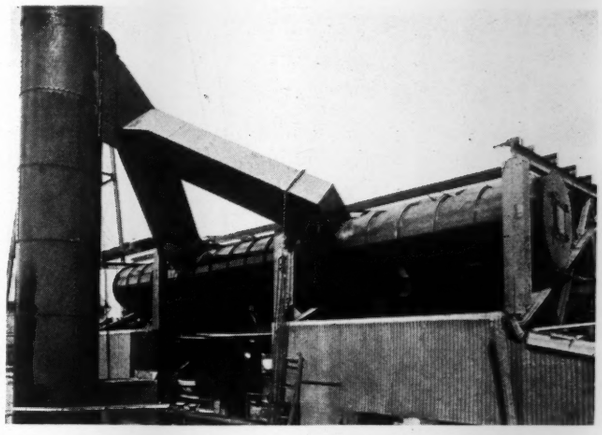
A very complete system of stairways and access platforms is desirable in a lofty installation of this sort. Practically all valves, clean-outs, and places of adjustment in the plant may be reached by self-cleaning and safe platforms like the one shown

Coal and Ash-Handling Equipment

Coal is unloaded from cars by hand and by an electric portable conveyor and is distributed with the aid of an electric belt conveyor over an enclosed storage area at the end of the boiler room.

A screw conveyor under the storage pile with a bucket elevator at its end moves the coal mechanically as required to an overhead screw conveyor which distributes the coal within a steel bunker above the coal pulverizers.

The top of the screw under the coal pile is covered over by 12 in. x 12 in. x 2 in. loose wood blocks, set with their tops flush with the floor line. These blocks may be removed successively as the coal pile is exhausted so as to allow coal to feed gradually into the conveyor.



Old chimney and new breeching prior to installation of the roof. The Y-shaped uptakes extend into the center zone of the breeching cross-section, midway between the boilers

The controls for the various conveyors are so interlocked and safeguarded and the speeds are so regulated that there is automatic avoidance of overloading the hopper of the elevator with coal or of overflowing the overhead bunker.

From the bottom of the coal bunker, spouts provided with spiral coal meters and hand-operated coal gates extend to the hoppers of each pulverizer.

Ash which collects in the combustion chambers of the boilers is dragged out manually with hoes through clean-out doors in the front and side walls. It is wheeled to the hopper of an enclosed auxiliary bucket elevator at the boiler-room floor level, and from this elevator is discharged into the closed elevated ash bunker outside of the boiler house.

The Auxiliary Equipment and Instruments

These are two centrifugal boiler-feed pumps, one driven by a steam turbine, and the other by an electric motor. The exhaust steam from the turbine is used to heat the boiler feed water and the heating radiation in and near the boiler house. The turbine always is a ready stand-by in emergencies, and is operated while the conditions permit condensing its exhaust steam.

There are automatic water-line governors for each boiler.

An automatic electric-motor-driven vacuum pump on the returns from the various heating systems discharges condensate into an open receiving tank located at the highest practicable point in the boiler house. Make-up water is fed to the receiving tank automatically if the water level in the tank should fall below a pre-determined level.

From the receiving tank, the water flows down by gravity to an open de-aerating feedwater heater, and from this to the suction side of the boiler-feed pumps.

Indicating pressure gages and steam flow meters are provided for each boiler, with the indicators mounted on individual steel instrument panels at the front of each boiler. On each of these panels is mounted a battery of draft gages which indicate for each boiler:

a Air pressure at uptake

b Air pressure in furnace
c Air pressure in right wall
d Air pressure in left wall
e Air pressure at burner

The electric control switch for each pulverizer motor is mounted on the corresponding boiler instrument panel. The center boiler panel carries an indicating electric thermometer with selective switches for registering flue-gas temperatures at each boiler uptake.

In the engineer's office there is an instrument panel on which the following are mounted:

Recording and integrating steam flow meter showing the total steam output.

Recording steam pressure gage and recording feedwater temperature thermometer.

CO_2 recorder.

Operating Results Show Savings Obtained

The cost to the owner for the new boiler plant, including removal of the old plant and remodeling and reconstruction of the boiler house, pump room, and coal storage areas, was about $109,000.

Comparative operating cost data are presented in the accompanying table, together with comparative data for a heating season when the old boiler plant was in service. The new plant operates normally at 90-lb gage pressure.

Heating Season	1 Pounds Steam Produced	2 Pounds Coal Burned	3 Coal Cost Per Ton	4 Total Cost of Coal	5 Labor Cost
Old Plant					
1924-1925	37,294,326	5,713,500	$4.00	$11,427.00	$8,180.00
New Plant					
1928-1929	55,004,100	7,375,130	3.30	12,200.00	9,360.00
1929-1930	58,870,646	7,435,035	3.26	12,100.00	7,850.00
1930-1931	45,468,900	5,428,930	3.00	8,113.00	5,030.00
1931-1932	44,824,166	5,422,000	2.75	7,455.00	3,552.00

Heating Season	6 Supplies Maintenance Repairs Burden	7 Fixed Charges	8 Total Cost	9 Coal Cost per 1,000 lb Steam	10 Total Cost per 1,000 lb Steam
Old Plant					
1924-1925	$ 7,520.00	$ 2,690.00	$29,817.00	$.307	$.800
New Plant					
1928-1929	11,480.00	14,846.00	47,886.00	.222	.869
1929-1930	4,227.00	14,854.00	39,031.00	.206	.665
1930-1931	1,141.00	6,780.00	21,064.00	.179	.465
1931-1932	1,583.00	6,256.00	18,846.00	.167	.420

It is to be noticed in the table that the charge for Supplies, Maintenance, Repairs and Burden, *Column 6*, during the first year after the new plant was in operation, seems excessively high. This charge includes many items of new work and additions that might fairly have been capitalized instead of being charged as an expense.

Fixed charges for the first two years of the operation of the new plant are much higher than the same item for the succeeding years. This is explained by the bookkeeping department's method of depreciating in two years the installation labor charges of equipment, and the method of depreciating the cost of the equipment itself over a longer period, depending on its expected useful life.

The 1931-1932 reduction in cost is due also to the effect of longer experience and increased skill in operating the plant. For instance, if in 1929-1930 the 58,870,646 pounds of steam which was produced, had been gained, as would have been possible, with the 1931-1932 overhead charges and at the 1932 fuel cost per ton, the cost per 1,000 lb of steam including fixed charges would have been only $0.36.

Preventing Steel in Storage from Rusting

An interesting "air-conditioning problem" came up on this job. It was noticed that the steel stored in the strip-steel warehouse rusted badly, even though it was stored in a very large glass-enclosed warehouse, and was protected by a tight roof. It had been known for a long time that the steel in the heated warehouses apparently did not rust. Therefore it was desired that the particular warehouse in question should be heated.

It was found, however, that about 150 additional boiler horsepower, which wasn't available, would be required to heat the building, and that very heavy expenditures would be required in trying to make the vast old shed-like structure fit to heat. It was suggested, therefore, that a little research be done to devise a less costly alternative.

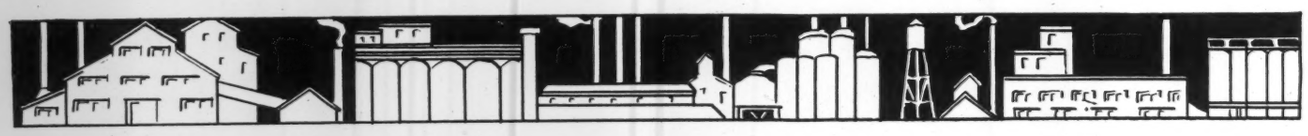
A few days with a psychrometer and a little common brain exercise disclosed that no moisture to cause rust could reach the steel unless some one carried the moisture into the building and deposited it on the steel. There was excess humidity always around the drinking-water tap, where, after drinking, everyone would throw the waste water out on the floor, but no other visible water was being carried in. In cold weather often there would be frost-whiskers on the steel and this stayed until it melted; the steel would be wetted thereby and would develop rust.

It was obvious that the trouble was due to the fact that the temperature of the metal does not respond quickly to changes in the air, and so, after cool weather, when the air would warm up quickly, the steel, kept out of the sunshine, remained cool for many hours, and caused the air which came near it to reach the dew-point temperature.

At a trifling cost (about 5 per cent) compared to the cost of a new boiler plant and a heating plant for the warehouse, a few long steam pipes were pushed through under the existing piles of metal. Close watch is kept of the temperature and humidity throughout the plant, and whenever it has been cool and suddenly turns warm you will find a little heat in these pipes under the steel, and no dew on the metal.

The conditions which call for "anti-dew prophylaxis" may occur in August or in January, and in either case this treatment is effective.

Acknowledgment is made of valuable suggestions and effective cooperation in the design, installation and operation of this boiler plant by Vernon G. Leach, combustion engineer of the Peabody Coal Company of Chicago.



Survey *by* Utility Company Shows 18,860 Tons Refrigeration *for* Air Conditioning *in* Chicago

A SURVEY just completed by the air-conditioning department of the Commonwealth Edison Company, of which G. A. Freeman is the manager, shows a total refrigeration capacity of 18,860 tons installed for air conditioning a variety of buildings in Chicago proper. In addition, some 500 tons of refrigeration were installed for air conditioning at the World's Fair last summer. The total number of installations made during 1933 was 156, including 26 at the Fair, according to the survey.

Types of installations classified in the listing include banks, brokers' offices and exchanges, beauty shops, churches, civic buildings (Planetarium and Art Institute), clubs, dance halls, dentists' offices, drug companies, hospitals, hotels, industrial applications (candy, bakeries, printing, miscellaneous), general offices and office buildings, packing plants, ticket offices, private offices, restaurants, stores (candy, clothing and shoe, food, miscellaneous), studios, trade-association offices, undertakers, theaters, and residences.

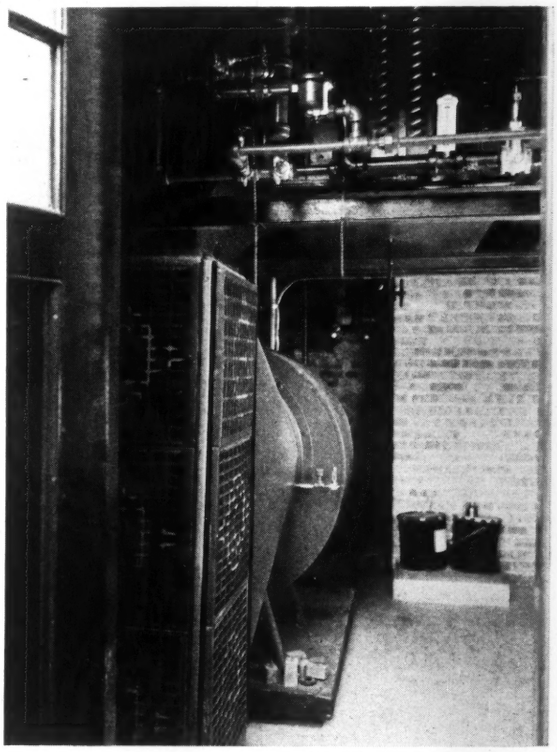
The survey shows that 48 Chicago theaters have refrigeration for complete air conditioning; the total tonnage is 7,742, total summer horsepower, 13,671. Total seating capacity of the 48 theaters is 114,421, and the average seats per ton is about 15. Twenty-two theaters with washed-air systems have a total seating capacity of 17,285, a total summer horsepower of 345.

One bank building has 120 tons of refrigeration, and fan, pump, and refrigeration horsepower amounts to 200 hp; a second bank has 300 tons and 476 hp; a third bank, 55 tons and 100 hp, and a fourth bank 250 tons and 403 hp. Three private offices and a directors' room in the fifth bank building listed require 16 tons and 27 hp.

Six dance halls are listed, two with refrigeration. These have 225 tons and 300 hp, and 100 tons and 150 hp. The 4 dance halls with washed air systems require 10, 5, 5, and 3 hp for fans and pumps. The 19 hotel installations (some hotels with two or three different installations) require a total of 1700 tons of refrigeration, and 3959 hp for fans, pumps and compressors. Two of these installations have no refrigeration.

The 26 candy plant jobs included in the listing have a total of 1796 tons of refrigeration and fan, pump, and refrigeration horsepower totaling 3,174; the 18 bakery jobs (3 of which have no refrigeration) show a total of 173 tons of refrigeration and 299 hp. The printing-plant installations total 15 (9 with no refrigeration) and have a total refrigeration tonnage of 770 and a fan, pump, and compressor horsepower of 1627.

REAL-ESTATE FIRM HAS AIR-CONDITIONED OFFICES



Shown here is one of the new air-conditioning installations in Chicago's Loop, that for the offices of Frederick H. Bartlett & Company (real estate). Occupying the second floor of a new two-story flat-roof building, the problems of street noise and dust and heat gain through the roof made air conditioning desirable. A 10-ton compressor provides refrigeration, city water being used when the temperature is low enough. Air introduction is through outlets concealed by the lighting fixtures; return air ducts are concealed on inner walls. In Mr. Bartlett's private office, air is taken from the room through a decorative screen in the fireplace opening.

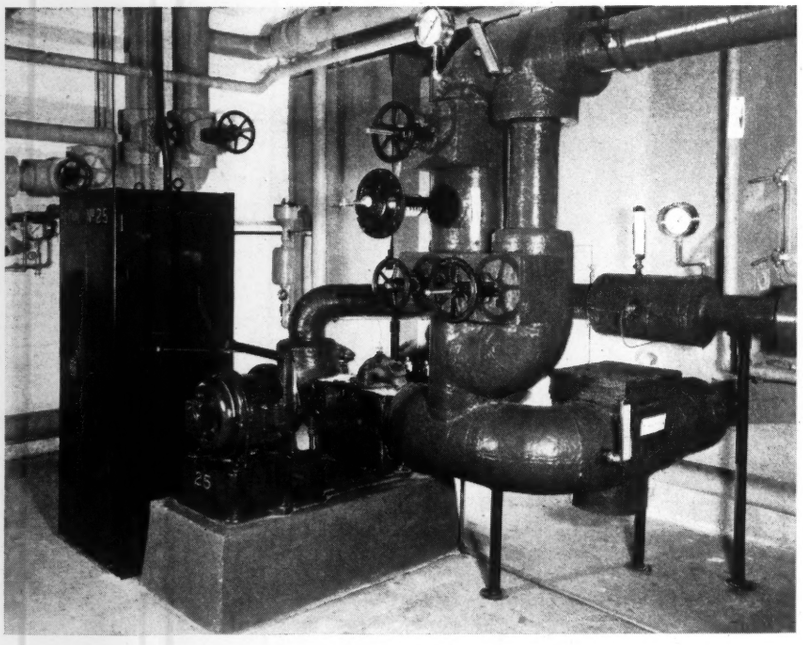
86 Shops

at Radio City

Air Conditioned

BECAUSE it is a part of the world's largest air-conditioning project and because of the many mechanical, electrical, and architectural features, the R. C. A. Building at Rockefeller Center (Radio City) has created much interest.....This article describes the air-conditioning system for the eighty-six high-grade shops in the concourse, on ground level, and on the mezzanine of this building.

By **André Merle***



IN the R. C. A. Building[1] at Rockefeller Center, New York City, some eighty-six high-grade shops of every description are air conditioned. Twenty-five of the shops are in the concourse, thirty-seven on the ground and twenty-four on the mezzanine. Their rentable area totals 103,405 sq ft and the inter-connected pedestrian lanes or corridors are well over three-quarters of a mile in length; it has been estimated that well over 200,000 people will pass through these corridors daily and view the merchandise displayed.

Air Distribution System Has Four Zones

For simplicity of operation and control, the building is divided into four zones; each consists of one-quarter of the concourse, ground and mezzanine floor.

Each of the four groups of apparatus which serve these zones employ one spray-type dehumidifier and two supply fans. One of the fans handles the concourse and the other the mezzanine and ground floor. 120,000 cfm of conditioned air is circulated by the 12 supply fans. The four dehumidifiers will handle about 80,000 cfm.

The air distribution system consists of a series of well-insulated galvanized-iron ducts which are located at the ceiling line, over the show windows. The conditioned air to each shop is introduced by means of double-duty ejector outlets, located in the wall close to the ceiling. The return grilles are close to the floor.

A novel system of automatic temperature and balanced humidity control maintains the desired conditions. Of particular interest is the combination indicating-recording controllers, which are compactly arranged on a central control panel adjacent to the air-conditioning apparatus. Arranged in this manner, they simplify and reduce to a minimum the adjustments and readings normally required for operation.

The Pumps and Cooling Towers

All of the pumps for the chilled, dehumidifier sprays, condenser water and cooling-tower make-up, are of the volute centrifugal design. They have flat water-rate characteristics with but slight increase in head. The pumps, designed for heavy duty and to be efficient and quiet operating, are of horizontal, split-shell, double-suction type, directly connected to constant-speed electric motors. The upper section of each pump casing can be removed without disturbing the water piping.

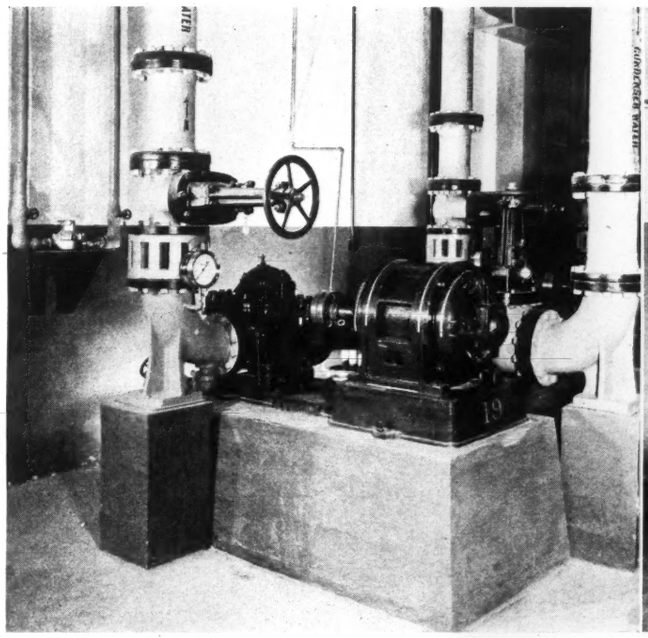
Ten pumps with a capacity of 2,000 gpm of condenser water were installed. A like amount of chilled water will be circulated each minute in the four dehumidifiers.

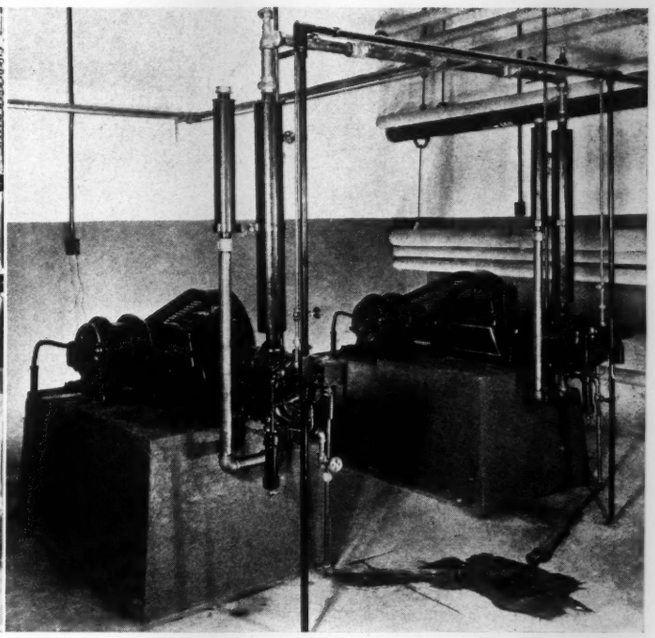
Two spray-type forced-draft cooling towers cool the condenser water. Each is 27 ft high, 16 ft wide and 25 ft long. They are located on the 16th floor extension of the R. C. A. Building on the Sixth Ave. side. The towers will cool the water approximately 10 F when the water enters at not over 83 F and the outside wet-bulb

*Air-Conditioning Engineer, Staff of Clyde R. Place, Consulting Engineer, New York City.

[1]The R. C. A. Building is a huge structure which forms the center core of Rockefeller Center. It is located at Sixth Ave. between 49th and 50th Streets, in New York City. This 70-story edifice rises well over 850 ft above the street and has a rentable floor area in excess of 2,083,000 sq ft, the largest office building in the world.

The architects were Reinhard & Hofmeister, Hood, Fouilhoux & Corbett, and Harrison & MacMurray. The builders and general contractors were Hegeman Harris Company. All of the mechanical and electrical engineering design and specifications were performed by the staff of Clyde R. Place.





Left—The dehumidifying apparatus room; note control valve in suction of spray pump. . . . Center—Condenser water pumps, showing check valve and gate valve in discharge line. . . . Right—Air compressors; note rugged concrete foundations and water bleed line. Below—Typical cross-section through shops

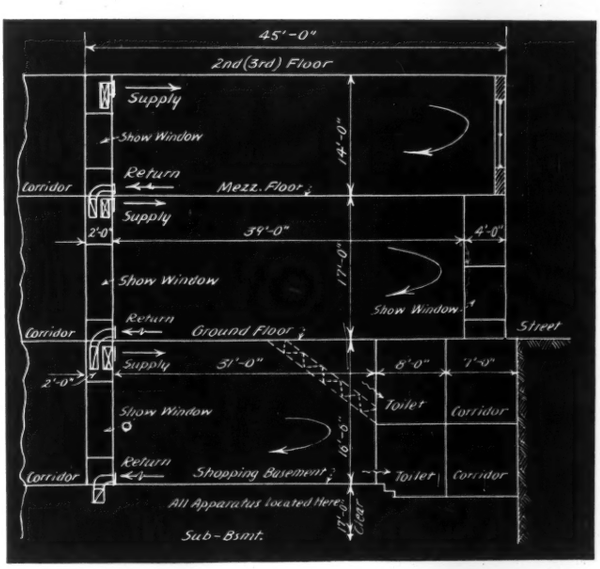
temperature is 75 F or lower and the dry-bulb not over 95 F.

At the base of each tower are two 9-ft impeller type, double-stage fans. Each fan will handle 78,000 cfm of air, a total of 312,000 cfm.

Automatic Air Compressors for Control System

A constant and adequate supply of clean, dry compressed air is one of the important requisites of any pneumatic system of control. Two horizontal motor-driven 5¼ in. x 4 in. compressors insure delivery of the compressed air required. Each compressor has a displacement of 30 cu in. with an actual air delivery of 23 cu in. They do not exceed a speed of 300 rpm and deliver air at 60-lb pressure to a central air receiver 5 ft 0 in. high and 24 in. in diameter.

Each compressor is provided with forced feed lubrication and the added feature of complete automatic water control.



Two 300-Ton Refrigerating Machines

Two centrifugal refrigerating machines have been installed and space for a future machine reserved. These machines each have a capacity of 300 tons per 24 hours, which tonnage is required to chill the dehumidifier spray water used for air cooling.

The refrigerating machines, along with all auxiliaries necessary for a complete system, are in the sub-basement. From this point the chilled water is pumped to each of the four dehumidifiers. After it has been sprayed in the dehumidifier chamber it is returned by gravity to a receiving tank under the refrigerating room floor. The tank is made of concrete and is 30 ft long, 8 ft wide and 7 ft 6 in. deep. The water which has been returned to this tank is then pumped to refrigerating machines and chilled over again.

Duct Insulation and Machinery Isolation

All of the supply ducts are insulated because of the low air temperatures and long runs. The various fans, pumps, dehumidifiers and both the steam and chilled-water piping are also insulated. The possibility of sweating and heat loss or gain has thus been eliminated and a degree of sound prevention obtained.

Machinery such as fans, pumps, air compressors and refrigeration units are isolated so as to prevent vibration. Flexible rubber joints are provided between the water piping and pump suction and discharge; duct connections to and from the fans are separated by canvas collars. These precautions have resulted in relatively quiet machine rooms.

[*By* G. E. Deatherage*]

Welding *Non-Ferrous* Process Piping

INCREASED use is being made of the oxy-acetylene welding blowpipe as a joining tool for copper and aluminum piping in chemical and other process industries where resistance to corrosion from liquids and gases is a serious factor. It is of interest in this connection to review the materials and methods used recently in the fabrication of an extensive process-piping system in the chemical industry, not only because of the severe service conditions under which the system is designed to operate, but also because of the advantage taken of the recently-developed copper sweat-type fittings.

Choice of Material

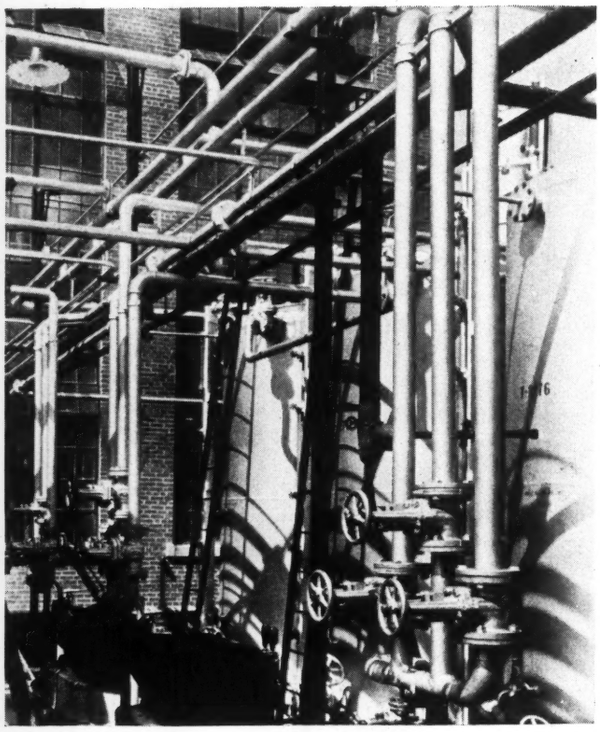
Each specific problem of corrosion and temperature demands special consideration with regard to the materials with which it may be met. It is unusual to find that a single specification of piping material, rod, and flux will meet every condition. That which gives the best results on one liquid or gas may not work with another. Likewise, a joint suitable for one given temperature may not be suitable for a line which is working at a relatively higher temperature.

The materials selected for each case, then, should be subjected to extensive laboratory or field tests that duplicate as nearly as possible actual working conditions. The selections are then made on the basis of performance. Corrosion tests not only point out the best alloy to use, and indicate the gage of tubing or piping required to insure the desired life of the line, but also determine the welding rod most suitable for the service.

The matter of expense also enters the question. When tests show that two different materials, either for the pipe or for fabricating the joint, are equally suitable for a given service, the less expensive material is indicated. Cost, then, becomes an important factor for consideration.

In the particular installation under discussion, the tubing selected included 3SH aluminum in Nos. 10, 12, 14, 16 and 18 gage as well as I.P.S., and oxide-free copper tubing known as "deoxidized," which is necessary for proper fusion welding.

*Carbide and Carbon Chemicals Corporation.



Process piping and equipment fabricated by oxy-acetylene welding

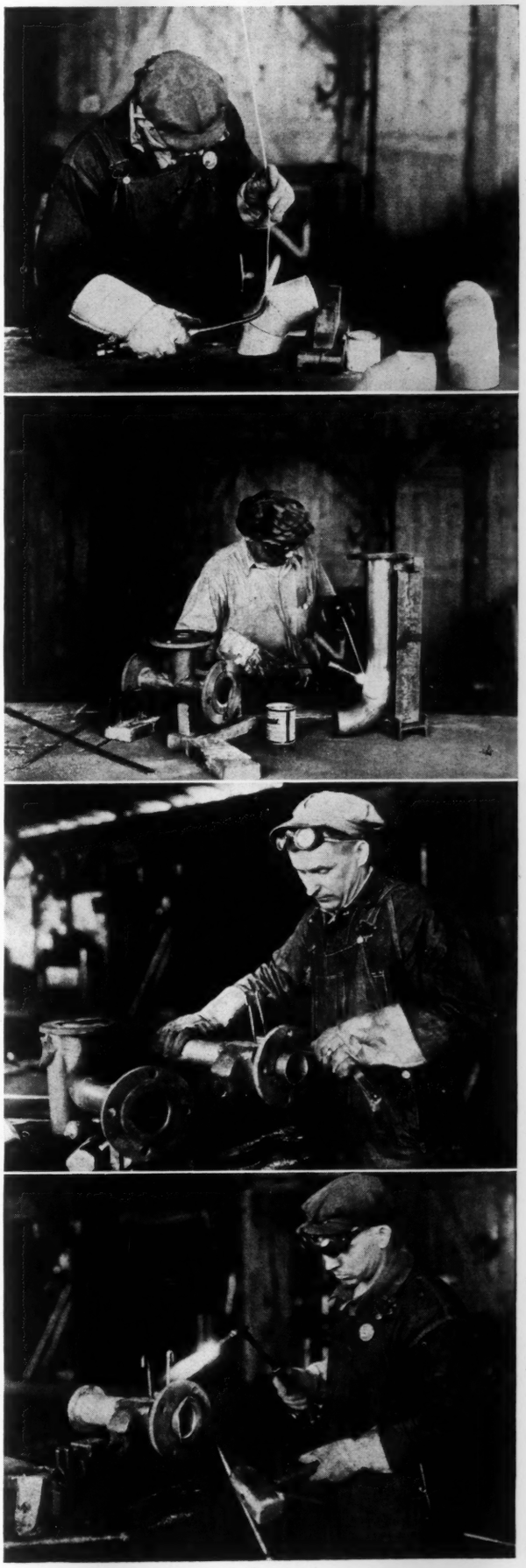
While the entire pipe system in the chemical installation utilized both copper and aluminum pipe, depending on the particular service to be encountered in the different units, it is more convenient to consider the two types of material separately.

Aluminum Piping System

For the aluminum piping system, all turns and bends 6 in. in diameter and over were purchased, and those smaller were shop fabricated on the job location.

With the exception of the elbows, all other fittings such as tees, branches, crosses, etc., had to be shop fabricated in all sizes. Inasmuch as the templets for standard steel pipe would not properly fit the aluminum piping except the I.P.S. pipe, it was necessary to have templets developed by the field forces. With these in the hands of experienced welders, fittings were easy to fabricate.

Tests previously carried out showed that a saving could be obtained by fabricating aluminum Van Stone flanges on the job. As all valves were connected in the lines by Van Stone joints this became an important factor in reducing the total cost of the piping installation. With Van Stone joints made in this way the lap is naturally thinned out to less than its original thickness, and consequently, they were used only for low-and medium-pressure service. For higher pressures a circular aluminum flange was cut and welded onto the pipe so that there was no diminution of the original thickness.



Top to bottom—All-aluminum elbows under 6 in. were oxy-acetylene welded miter turns . . . Silver solder was used for copper sweat-type fittings for medium-temperature service . . . Von Stoning copper pipe on job proved economical and practical . . . Van Stoning aluminum tubing

Field Fabrication Methods

All aluminum joints including both the fabrication of aluminum fittings as well as the welding into the line of prefabricated fittings were made by usual aluminum oxy-acetylene welding methods, using a drawn aluminum welding rod and aluminum flux.

Copper Piping System

The installation of the copper system entailed a wider variety of work than did the aluminum, due to the greater range of temperatures encountered.

Depending upon the temperature conditions, the methods for joining the copper tubing fell into three classes:

(1) Fusion-welded joints made with copper welding rod, for use where the highest temperature conditions prevailed. It is important to note that the base metal and welding rod were completely deoxidized.

(2) Bronze-welded joints, made with a new all-purpose bronze welding rod for moderate temperature service.

(3) Silver-soldered joints, for maximum corrosion problems at temperatures lower than the melting point of this bonding agent.

Fittings

The various elbows and bends for copper pipe, except those under 3 in. diameter, were all purchased prefabricated. As manufacturers carry standard lines of practically all sizes they were easily procured.

Van Stone flanges were fabricated on the job, except for high-pressure work where regular manufactured Van Stone welding stubs were purchased.

An illustration shows Van Stone flanges for low-pressure work being made. The tubing is first heated slightly with the blowpipe flame and peened over with a wooden mallet. The gasket face is finally finished off smooth with a fine file. This type of joint was required for connecting valves in the line. Properly made, it will hold tight up to the bursting point of the tubing.

As in the aluminum work, tees, branches, crosses, etc., were shop fabricated, using templets developed by the field operators.

An interesting feature of this installation was the use of copper sweat-type fittings for low- and moderate-temperature work. Fittings of this type for copper tubing are made by several manufacturers, are convenient and economical where it is possible to use them.

These fittings, some of which are shown in the illustrations, are ordinarily used with solders which melt at quite low temperatures. In the work under discussion these solders could not be used on account of their inability to resist corrosion and high heat.

In this installation, sweat-type copper fittings were joined as follows:

(1) For low-temperature service, by means of silver solder, which has a melting point of about 1,300 F.

(2) For moderate temperature service, by means of bronze welding rod, which has a melting point of about 1,650 F.

As these temperature ranges are beyond the heating ability of the gasoline blow torch or the simple air-acetylene flame, the oxy-acetylene blowpipe flame was used. It was found that the fittings worked just as well with these high-melting-point solders and rods as with the low-melting-point solders for which the fittings were originally designed.

Copper "sweat fittings" are threadless. They slip over the pipe with a very close tolerance. The fittings and adjacent piping are then heated with an oxy-acetylene flame to a temperature higher than the melting point of the hard solder or bronze rod to be used. Flux is applied and the rod is melted into the joint, where it is drawn in and around evenly by capillary attraction.

After erection, all piping was subjected to an air test of 1½ times the working pressure.

The methods used in the preparation of drawings, the billing and purchasing of the required material, job management, and other organization details,—which when carefully studied and carried out on a preconceived plan markedly reduce installation costs,—were no different than handling those same matters in any welded piping installation. One point to bear in mind is that in purchasing aluminum and copper piping material, the larger the order the less the price per item. Small quantities carry an extensive extra list and materials should be bulked as much as possible to secure the lowest price. In other words, the complete materials list should be worked out before ordering anything at all, if possible.

With qualified welders, the work quickly develops into a routine requiring no more supervision than the familiar steel welded job. In this connection it is well to remember that the qualification tests should be planned so that they conform to the work that is to be done. In other words, material, rod, technique, and position for welding should duplicate as nearly as possible the work that will be encountered on the job itself.

Air Conditioning Insures Purity

Down on the Farm

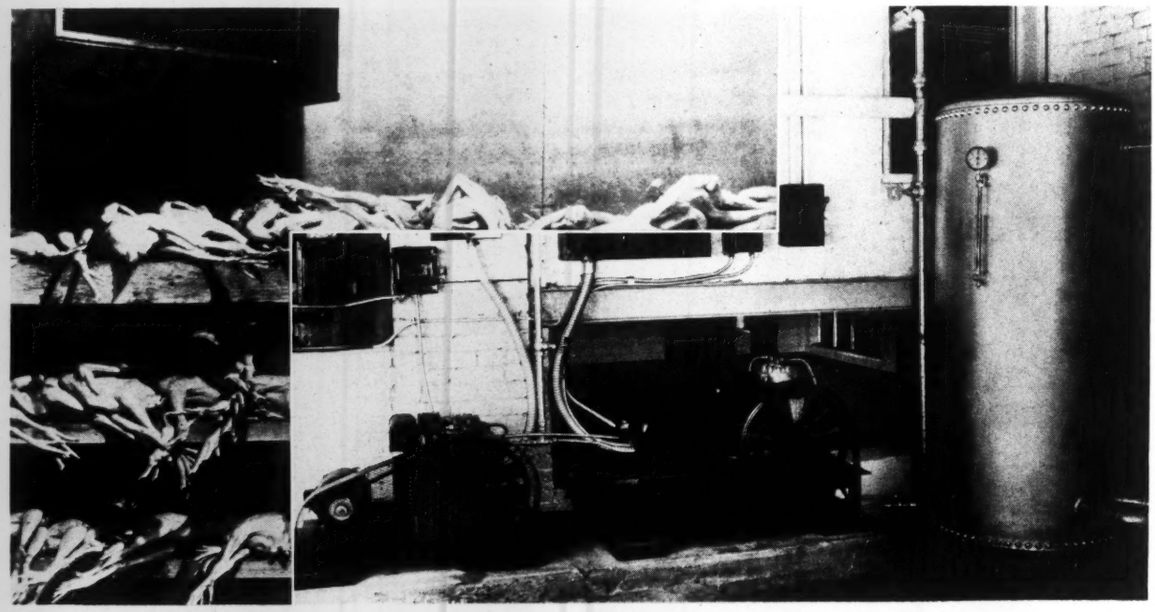
REPRESENTATIVE of the increasing uses to which air conditioning is constantly being put is the installation in the wrapping room of the Van Wert Butter Company, Van Wert, Ohio. Uniformity of temperature and cleanliness are prime requisites in the manufacture of butter, and many food products. The specific problems which air conditioning has solved on this job are to prevent the butter softening during the wrapping process and prevention of the butter picking up odors.

The wrapping room, which is 18 ft x 9 ft x 10 ft, is conditioned by a floor-type room cooler, refrigeration being supplied by a ½-ton compressor. The room is used only for wrapping, three days weekly, four hours per day, two people wrapping. As the room was formerly used for ice-cream hardening, it is well insulated with from 6 to 8 in. of cork. There is no heat gain through the two 18 x 10 walls, as a butter storage room at 35 F is on one side and a keg beer storage room at 45 F on the other. Temperatures held in the wrapping room run 60-70 F.

The storage room, which is the same size as the wrapping room, has coils arranged close to the ceiling and extending along one entire side; a 1½-ton compressor supplies refrigeration. There are two expansion valves. The refrigeration thus provided keeps this room within 3 F of that desired, despite the peak daily product load of 1600 lb of freshly-churned butter and 200 gallons of cream in cans brought in by farmers.

Illustrations courtesy of Albert W. Bailey, Frigidaire Corporation.

Right—The two compressors which furnish refrigeration for the Van Wert Butter Company....Left—Air conditioning also serves the poultry farm. At Young's Poultry Farm, Mercer, Pa., poultry is cooled a short time after killing, the product is clean and free from excess moisture, with no discoloration and consequent losses. Two thousand birds are handled every two days. The illustration shows the dressed birds in the cooler



Industrial Fan Drive Applications
. . . V-Belt, Flat Belt, Chain

By Robert W. Drake*

THE AUTHOR pointed out in an article last month that important savings in power are obtainable with many industrial ventilating and exhaust systems by changing fan speeds as may be possible, depending upon the service required from the particular system under consideration . . . . . His article this month describes the applications of V-belt, flat belt, and chain drives for industrial fans, will be found of especial interest by operating men.

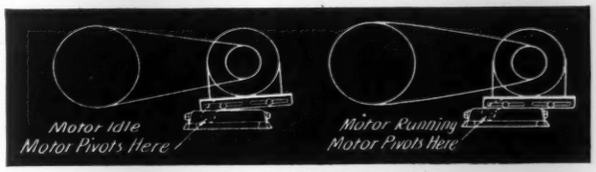


Fig. 1 (Above)—Diagram illustrating pivoted-base flat-belt drive

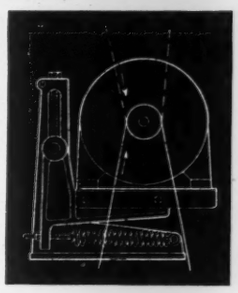


Fig. 2 (Right)—Spring-loaded overhead-type pivoted-base drive

THAT industrial fan drives offer worthwhile opportunities for saving in cost of power was pointed out in an article last month[1]. It is the purpose of this month's article to consider the power savings which may be realized in many fan installations by means of mechanical transmission equipment for pressure variation through control of speed or otherwise. It is the writer's experience that more than half of all industrial fan installations are:

Installations where there is a seasonal variation in air requirements—slack season and busy season, summer and winter, etc.

Installations where provision is made in the original design for growth of load.

Installations where flow decreases with the passage of time due to ducts accumulating an incrustation of dirt and lint. If provision is made in the original design for this, much power can be saved during the early years by operation at reduced pressure. If no such provision is made, a reasonable speed increase will ordinarily give tolerable performance in spite of incrustation. Of course such ducts as will pass a man should be cleaned, but complete cleaning of the branch ducts where most of the friction drop occurs is seldom possible. Even the dragging of burlap sacks stuffed with excelsior to remove the plush-like coating of lint is relatively ineffective, particularly in rectangular ducts.

In many applications the infrequent changes in speed necessary to operate with a minimum power consumption consistent with satisfactory performance may be provided for by changing a pulley, sheave, or sprocket on the driving motor at long intervals; spring and fall, perhaps, or even once in two or three years as the load grows or as duct incrustation increases.

There are various types of drives available which permit such speed changes. First in order of general applicability should come short-center belt drives of various sorts—rubber v-belts, flat leather belts, flat rubber belts, etc.

Flat Belt Drives and Their Applications

At present there are in common use in connection with flat belts two devices which permit the installation of the motor very close to the fan and maintain a correct tension on the slack strand of the belt sufficient to assure a combined belt creep and slip of less than 1 per cent (generally less than ½ per cent). Ordinary open drives on short centers with flat belts of any material are likely to prove troublesome, particularly when there is a great disparity in pulley sizes, as is frequently the case with fan drives. These two mechanical devices for automatically maintaining the exact belt tension needed to assure adequate grip of belt on pulley are (1), the pivoted motor base drive (shown in several of the figures), which is applicable where the larger pulley is not more than six to ten times the diameter of the smaller pulley, and (2), the idler drive, applicable regardless of the disparity in diameters.

The type of pivoted-base drive shown in principle in Fig. 1 is applicable when the motor shaft is not higher than the fan shaft; the type shown in Fig. 2 is necessary when the motor is to be mounted above the fan, and occasionally when the motor is to be mounted directly below the fan.

The idler drive has been on the market for some years. Successful in providing a drive without slip, it has sometimes been criticised as resulting in short belt life. This is entirely unnecessary, though not unusual in practice. For instance, a drive such as that shown in Fig. 3*a* is likely to result in unsatisfactory belt life. The sharp reverse bend in the belt over an idler of small diameter is a severe tax upon the elasticity of a belt, particularly if the belt must be heavier than a light-double.

*Mechanical and Electrical Engineer, DeKalb, Ill.

[1] "Industrial Fan Drives Offer Power Saving Possibilities," by Robert W. Drake, HEATING, PIPING AND AIR CONDITIONING, December, 1933, page 595.

A drive such as Fig. 3*b* with an idler as large or larger than the smaller pulley of the drive located far enough from the small pulley so that the distance *A-B* is at least equal to the width of the belt will avoid such criticism. A drive as shown in Fig. 3*c* with a large idler at a distance from the small pulley about equal to one-fourth the center-to-center distance of driving and driven shafts is ideal and will give a belt life quite as great as an open drive.

There are many drives installed similar to the one

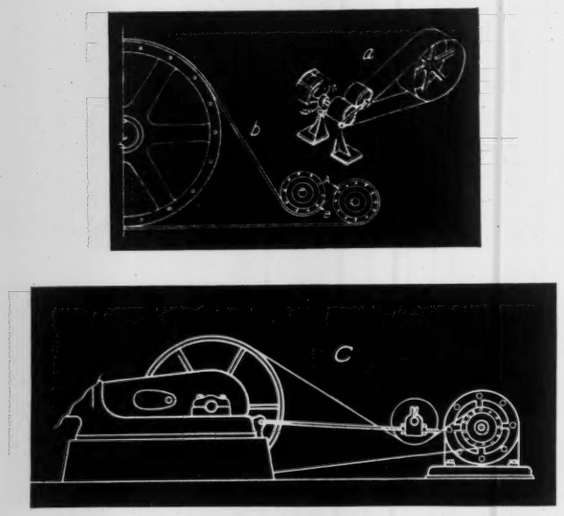


Fig. 3*a*—The sharp reverse bend in the belt in a drive of this kind is likely to result in unsatisfactory belt life. Fig. 3*b*—A drive with an idler as large or larger than the smaller pulley located far enough from the small pulley so that the distance *A-B* is at least equal to the width of the belt will avoid such criticism. Fig. 3*c*—Flat belt drive with idler

shown in Fig. 3*a* with idler or "roller" pulleys of small diameter located close to the motor pulley, resulting in a severe S-bend and frequently in a center crack along the belt. To improve such a drive, the idler pulley should be moved away from the motor pulley as far as possible. When belt replacement becomes necessary, a very flexible light double belt should be used. This recommendation for light double belting on idler drives pre-supposes that the smallest pulley of the drive is not less than six or seven inches in diameter, as is usually the case except on small fans. When one pulley is smaller than this a single belt or a special tannage belt is advisable.

The pivoted-base drive is inexpensive, simple, and has no bearings to wear out or to oil. It is quickly erected, for exact alignment during erection is unnecessary. There are adjustments in the base mechanism for bringing the pulleys into alignment in each direction. If an attempt is made to grossly overload such a drive beyond the load for which the motor position leverage is adjusted (usually 150 per cent of the rated motor capacity) the belt will slip and limit the motor load to the amount for which the drive is adjusted. This characteristic sometimes saves the fan motor from "roasting out" if the fan is overloaded during installation (through the electrician operating it, before the fan piping is connected, to see whether the bearings are going to heat up, for instance). Such operation is very hard on the belt but a "burned" belt is cheaper and easier to replace than a motor winding.

The idler drive's behavior on extreme overloads is entirely different from that of the pivoted-base drive. An idler drive will pull loads up to the stalling point of the motor with gradually increasing but moderate slip.

It may be well to briefly consider existing short-center open-belt drives to fans. In cases where such drives have required undue attention to avoid belt slip, the cure is to install a pivoted base under the motor, or a gravity idler, the choice depending chiefly upon the ratio obtaining between driven and driving pulley sizes. When operation on short centers without a mechanical tension device has been fairly successful, the substitution of special tannage leather belting generally improves the drive greatly. Combination tanned leather will ordinarily last longer than the straight mineral-tanned leather, while in pulley-gripping quality it approaches the latter.

Flat rubber belts are in general less used for fan drives than leather belts, but they have their place. The flat rubber belt is cheaper than a leather belt adequately proportioned for long, trouble-free service. With a motor on a pivoted base, it will carry a fan load quite satisfactorily except on such installations as require operation near the maximum capacity and speed of which the fan is capable. Under ordinary conditions the life of rubber belt is shorter than that of leather.

The life of oak leather belt is decreased materially if it is operated at temperatures above 125 F. Mineral-tanned leather should not be operated above 150 F. While both types of leather belting stand up well in damp locations (when made up with waterproof cement) and under mild steamy conditions, rubber belting is preferable in very wet, sloppy locations and when exposed to the weather as in some buildings, where the installation of air filters after the building is constructed has necessitated the location of both the filters and fans on a roof with very little protection.

V-Belt Drive Applications

By running V-shaped rubber belts or ropes in sheaves having V-grooves of proper angle, the grip between rope

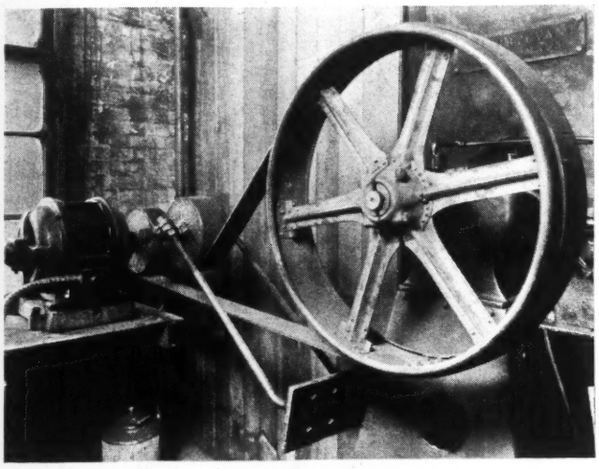
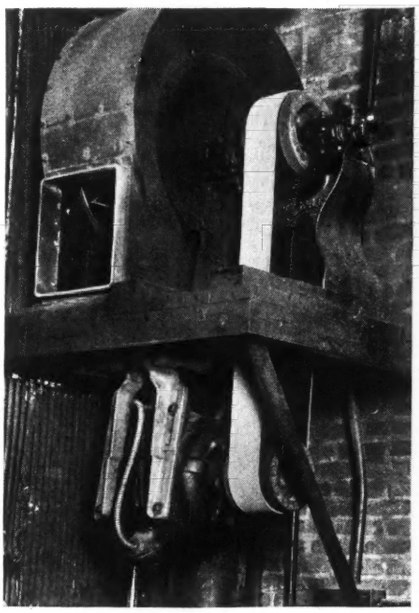


Fig. 4—Idler drive for ventilating fan. A paper idler pulley gave sufficient weight for this application



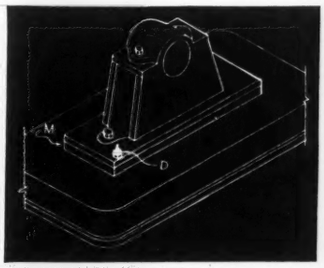


Fig. 6—Spare endless belt may be quickly installed by providing a kick-out block under the out-board bearing

M is the removable block somewhat thicker than the belt. *D* shows one of two substantial dowels, threaded at the upper end so that it may be easily pulled by stacking washers under the nut. The other dowel is of course at the opposite end.

Fig. 5 (Left)—Vertical pivoted base drive applied to a fan

and sheave surface may be increased about four-fold. The resulting multiple V-belt drive is supplied by a number of manufacturers.

As compared with drives using flat belting, this type of drive has certain advantages and certain limitations. It is important for the engineer in the plant to understand both.

V-belt drives have the advantage of greatly increased pulley grip, as compared with flat rubber belting. In comparison with flat leather belting, the V-belt drive, when loaded within reason, will stretch more slowly than leather belting. In the case of short-center drives without automatic means for maintaining sufficient belt tension to assure pulley grip, a rubber V-belt drive will run longer between take-ups than will a leather belt, particularly when the drives are both new. When grossly overloaded, rubber V-belts stretch as much as overloaded flat leather belts.

Where intelligent supervision may be lacking, and it is desired to install a V-belt drive with automatic tension adjustment requiring take-up only at intervals of years, a pivoted motor base may be used with a V-belt drive quite as usefully as with a flat-belt drive. An idler does not work well with V-belts.

It is worthwhile to consider the limitations of this drive, for they differ in several respects from those of flat belts.

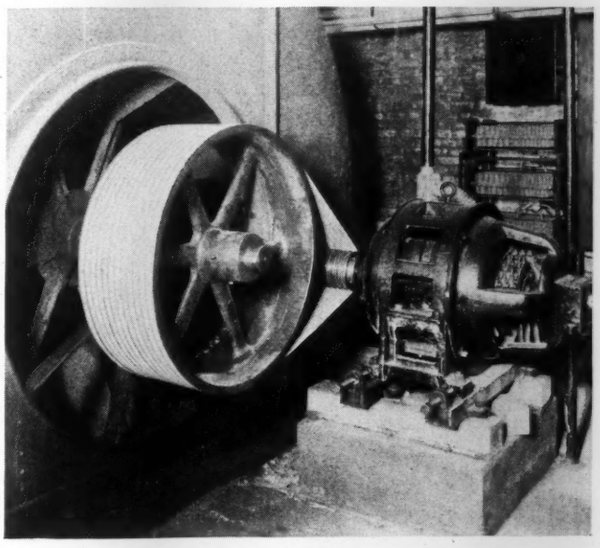
First, as to belt speed: Centrifugal force limits the speed at which any belt may be operated satisfactorily. At extreme speed the tension in the belt, produced by centrifugal force, elongates the belt like an elastic band. The additional slack thus produced interferes with proper grip between belt and pulley. At very high speeds, belt stiffness accentuates this effect, particularly in the case of pulleys of small and moderate diameter. Rubber V-belts are thicker, heavier and stiffer for the amount of power transmitted than are flat belts. As a consequence, the limitations as to extreme speeds are somewhat different than in the case of flat belts.

For long-lived, trouble-free drives involving one pulley which approaches the least practicable diameter for the belt thickness to be used, operating speeds for flat leather belts may well be limited to 3800 to 4200 feet per minute (depending upon belt thickness). Similarly with the smallest sheave diameters recommended for V-belt drives for the respective belt sizes, speeds may well be limited to 3200 to 3500 feet depending upon belt size.

For similar trouble-free service with pulleys of ample diameter, we may say that speeds for flat belts may well be limited to 5000 feet per minute, and for V-belts to 4000 feet per minute. It is true that operable drives may be designed having belt speeds above these limits. The improved belt life, reduced slip, and decreased maintenance which result when these conservative limits are not exceeded recommend them to experienced operating men.

When automatic means are employed to maintain belt tension close to the desired value, in spite of belt stretch and elastic elongation and without dependance upon the judgment of the operator, satisfactory operation may be expected at slightly higher belt speeds.

In most cases it is easy to design drives using either



50-hp V-belt drive, sheaves 6 in. and 38 in., 7/8-in. belts

flat- or V-belts which will keep well within these limitations as to belt speed. Those fan drives in which belt-speed limitations are of importance generally fall within one of the following classes:

Medium- or large-sized blowers designed for operation at pressures in the neighborhood of a pound or more, and other large fans designed for operation at or above 1500 rpm.

Fans driven by 1500- or 1800-rpm motors of more than 25 hp capacity. The obvious expedient in such cases is to use 1200- or 900-rpm motors.

In some of these cases, the use of flat leather belting with a mechanical device for maintaining adequate ten-

sion will permit the use of belt speeds just enough higher to make the difference between a successful drive and a troublesome one. Where this is impossible, the usual solution is a direct-connected motor-driven fan. In such an installation, speed changes, if advisable, require a motor whose speed may be varied.

Since V-belts cannot be spliced or jointed in the field, it is necessary partially to disassemble the fan in some way to replace ropes on installations where a bearing is necessary on each side of either the driving or driven sheave. Several means have been devised to facilitate rope replacement on such installations, such as the arrangement shown in Fig. 6.

Advantages, Limitations of Chain Drives

Chains are not used for fan drives as often as are the various types of belts described above. Nevertheless they have their place and would be more often used if they had been more intelligently applied in the past. The worst thing that can be said of chains for driving fans is that they have frequently been applied under conditions where they could not possibly be successful.

Chains have a somewhat limited field of applicability; chiefly in connection with drives of small and moderate capacity and for slow-speed applications. Outside of their natural field they are almost certain to be unsatisfactory. Let us then consider first the limits of this field.

Compared with flat- or with V-belts the permissible operating speed of the chain drive is low. For durable, trouble-free drives, and particularly if noise is objectionable, chains should not be operated above 1300 or, at most, 1500 feet per minute. Drives have been installed operating at chain speeds above 2000 feet per minute, but the conditions must be exactly right if such a drive is to give satisfaction over a period of years. Most successful drives at such speed really may be said to transmit only motion, practically no load.

In general, vertical chain drives should be avoided. They are operable if under regular inspection and if means are provided for taking up the slight slack due to wear in the link joints but if not so inspected and kept tight they will climb, jump, and even bend the driver or driven shaft.

If we consider 1500 feet per minute chain speed an outside figure for general application on fan motors (and in the writer's experience this is a little high for most types) then we are limited as follows for drives operated from motors at the various speeds:

For 1750 rpm motors the largest practical chain pinion is 3¼ in. in diameter.

For 1150 rpm motors the largest practical chain pinion is 5 in. in diameter.

For 850 rpm motors the largest practical chain pinion is 7½ in. in diameter.

For 680 rpm motors the largest practical chain pinion is 8½ in. in diameter.

For 570 rpm motors the largest practical chain pinion is 10 in. in diameter.

Motors differ in permissible bearing loads, but considering motors as they are being built now, and using the rough rule, that a chain pinion cannot be smaller than one-half the diameter of the corresponding *standard* motor pulley diameter without serious danger of motor bearing trouble, we may say that the chain cannot safely be used on motors of the different speeds in horsepower sizes larger than the following:

For 1750 rpm motors, largest horsepower on which chain is applicable, 3 to 5 hp.

For 1150 rpm motors, largest horsepower on which chain is applicable, 10 hp.

For 850 rpm motors, largest horsepower on which chain is applicable, 50 to 60 hp.

For 570 rpm motors, largest horsepower on which chain is applicable, 75 to 100 hp.

Note that when chain is used on motors as large as these listed in the above table the motor pinion size is fixed, and everything else must be fitted to it. When smaller motors are involved, more latitude is possible—the more latitude the smaller the motor.

It is evident that with 850-rpm motors it is possible to apply chains to most fan drives. For the less expensive higher speed motors which many users prefer on fan drives, it is evident that chain drives are applicable only to drives of moderate horsepower.

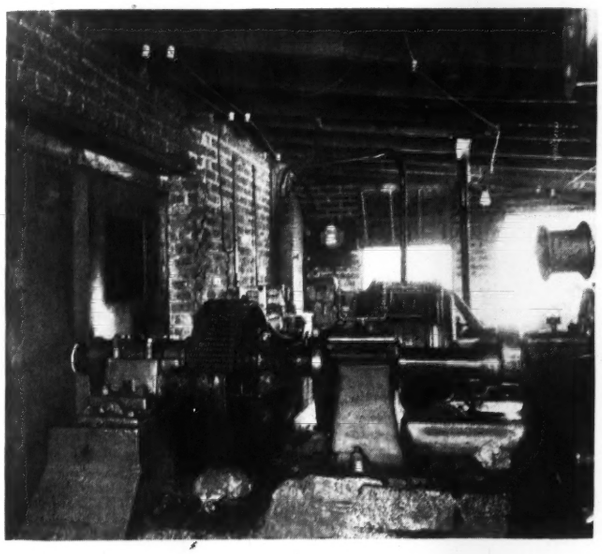
If a chain is driven at too high speed it becomes noisy and has an unsatisfactorily short life. In one such case which recently came to the writer's attention, such chain-driven fans became so noisy as to be objectionable in a railroad station. The resulting vibration loosens bearings in shells and sometimes mills through motor insulation. Noisy vibrating drives are also produced by an attempt to run chains over a pinion with too few teeth.

In planning any drive from a motor to a driven machine, the designer should consider the peak load which the drive will transmit, as well as the nominal rating or normal loads. Fans, in general, present a remarkably uniform load, but during the starting period the inertia of the fan runner forces the chain or belt to transmit nearly all the power which the motor is capable of developing. The more powerful the motor the faster it hustles the fan up to speed.

Thus, in the case of standard induction motors up to 5 hp ordinarily started "across the line" or the more recently developed line-start motors in larger capacities, it is usual to find the chain carrying twice normal tension or more during the later part of the starting period, three times normal tension and more is usual with single-phase motors which start with a commutator (repulsion start) or which run with a commutator (single phase series motors). As chains have been rated in the past, it is essential to make allowance for these facts in applying chains to fan drives. Where line-start motors are to be used, a chain of nearly or quite double the normal motor capacity is indicated, if long quiet service is expected free from vibration and trouble.

Now that we have covered the limitations of the chain drive, what are its advantages?

1. *Cannot slip.* The speed ratio between motor and fan is unchanging and absolute.
2. *Heat.* Under heat conditions which would destroy a rubber or leather belt in one hour, a chain will run along year after year provided that it is lubricated with a lubricant well suited to the temperature range involved. A lubricant which freezes solid at the temperatures prevailing when the drive starts is to be avoided if possible.
3. *Enclosures.* For the last ten years or more the tendency has been to enclose all chain drives except very small, unim-



Chain drive operating fan at a coal company

portant drives, particularly such drives if they operate at very low speeds.

The chain lasts longer if it is adequately oiled. In fact, most of the troubles ordinarily associated with chain drives are eliminated entirely or deferred for many years if the chain drive is conservatively designed and oiled continuously and well. Now such a drive cannot, generally speaking, be adequately oiled unless it is enclosed. Unless operated at very low speed it would throw oil all over the vicinity, and even at slow speed some receptacle for surplus oil is essential.

Satisfactory enclosures are fabricated at low cost from heavy sheet metal by welding. These enclosures are strong, light, practically oil- and dust-tight, and through simple but ingenious design, allow for the necessary adjustment in distance between shaft centers. They are split and can be installed and removed quickly even when neither pinion is overhung. When absolute dust-tightness is desired, cast-iron enclosures with machined joints are available.

Because of its enclosure a chain may be successfully operated under abrasive dust conditions, close to the floor if necessary, under conditions where the enclosure must be shovelled out and then cleaned externally before it is opened for inspection.

4. *Oil, Grease, Boiling Water, Steam.* Chain drives may be applied where oil or grease, boiling water or steam strike the drive continually; in fact, in some instances, when oil or grease are present continually and in sufficient quantity, enclosure and automatic oil flingers may be dispensed with.
5. *High Horsepower per Inch of Width.* Where space considerations limit the width of the face of the driven pulley, a chain will frequently fit in when nothing else but a gear is possible.
6. *Small Pinions.* Where the motor pulley *must* be so small that the motor bearings will not stand a belt drive of any sort, a chain drive will frequently run O. K. without producing dangerous motor bearing temperatures. In general, we may say that a motor pinion for the chain may be as small as half the diameter of the manufacturer's standard motor pulley without overloading the bearing. There are two reasons for this. First, the chain is narrower than a belt and may be placed close to the motor bearing, thus reducing the leverage. Second, the chain requires no tension on the slack strand, or practically none, at any load from full load to maximum permissible overload.

The space given above to chain drives may seem out of proportion. The rather full treatment given was suggested by the fact that very many ventilating and air conditioning engineers lack definite ideas as to the possibilities and limitations of this form of drive.

FLOW AND PRESSURE-DROP Calculations for Process Piping

By **Emory Kemler***

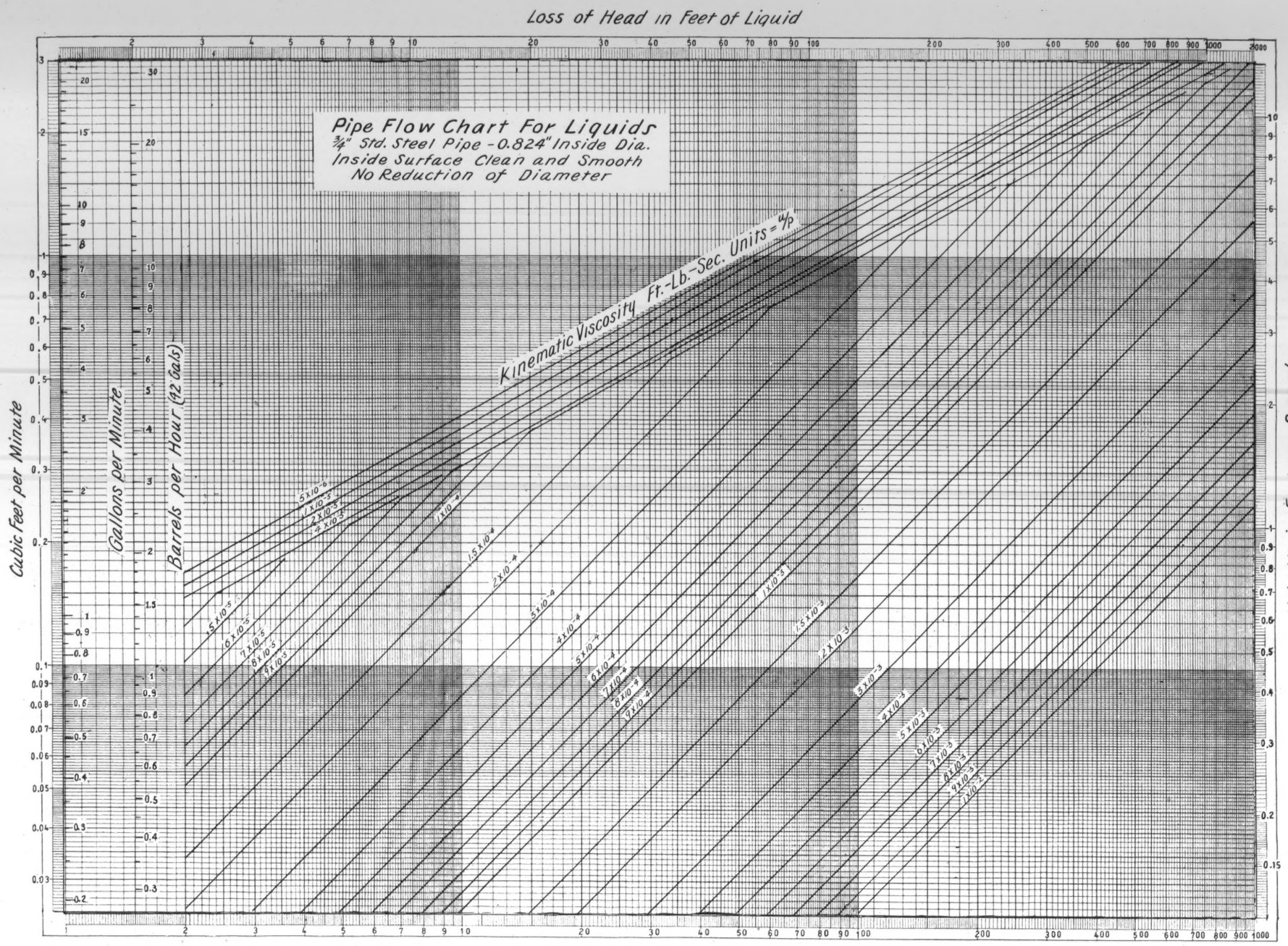
ON the next page is a chart designed to facilitate the making of pressure-drop calculations for liquids of various kinematic viscosities flowing in ¾-in. pipe. The complete series is planned to cover standard pipe sizes from ¼ to 4 in., the viscosities being chosen to cover a range that will take care of any ordinary process fluid that is being piped.

The first two charts to be published appeared in the October, 1933, issue and were for 1-in. and 2-in. sizes. A chart for 1¼-in. pipe appeared in November and a chart for 1½-in. pipe in December. An explanation of the charts and an example of their use also was published in October, as was a conversion chart for kinematic viscosity and viscosity in Saybolt seconds. Allowing for roughening and accumulations and turbulent flow were also discussed, and the following table showing how the pressure drop increases with increased amount of accumulations was given:

Per Cent Decrease of Diameter	Factor by which Pressure Drop should be Increased, per Cent
1	5
2	10.5
3	16.5
4	22.5
5	29
6	36

This explanatory material in the October issue should be referred to in connection with use of the chart published this month.

*University of Pittsburgh, Pittsburgh, Pa.


Loss of Head in Feet of Liquid
Pipe Flow Chart For Liquids
¾" Std. Steel Pipe - 0.824" Inside Dia.
Inside Surface Clean and Smooth
No Reduction of Diameter
Kinematic Viscosity Ft.-Lb.-Sec. Units = ν/ρ
Cubic Feet per Minute
Gallons per Minute
Barrels per Hour (42 Gals)
Velocity in Feet per Second
Pressure Drop in Pounds per Sq. In. per 1000 Ft. (Multiply by Specific Gravity)

Heating·Piping
and Air Conditioning

American Society of Heating and Ventilating Engineers

JOURNAL SECTION

JANUARY 1934

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Diurnal and Seasonal Variations in the Small-Ion Content of Outdoor and Indoor Air

By C. P. Yaglou* *(MEMBER)* and L. Claribel Benjamin† *(NON-MEMBER)*

Results of research carried out at Harvard University, School of Public Health, Boston, Mass., in cooperation with the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

IN a former paper[1] it was shown that the small-ion content of air of occupied rooms is rapidly depleted after the occupants enter, and that normal ionization is not restored until after the occupants leave the room. The present report presents the results of observations on the diurnal and seasonal variations in the small-ion content of outdoor air, and on the corresponding changes which take place in lightly occupied rooms, heated and ventilated by the usual methods.

Measurements of atmospheric ionization have been made by many workers in various parts of the world, notably by the Carnegie Institution of Washington[2] during the cruises of the *Carnegie* in the Pacific, Atlantic, and Indian Oceans, and by Nolan and Nolan[3] at Glencree Valley, Ireland. In all instances the chief interest centered on the ionization condition of outdoor air with little or no regard to changes in the ionization indoors and to the possible relation of such changes to air conditioning.

Situation of Building and Rooms

The observations to be described were carried out at the Harvard School of Public Health which is about two miles west of the Atlantic Coastline and about the same distance southwest of the Weather Bureau Station, from which some of the meteorological data not locally recorded were procured. The School is a three-story marble building with a flat cinder-fill roof. It has a basement floor partly below grade and a tunnel underneath the basement. It is surrounded by other school buildings and hospitals, all of which are supplied with heat and power from a central plant about 500 ft northwest of the recording station. Owing partly to this feature and partly to the unusually tall stack of the power plant, the air pollution in the vicinity of the recording station was not sufficient to affect the observations. However, during a brief period of street repairs, a number of readings had to be rejected because of contamination by tar smoke.

During the first year and a half (May, 1930, to Sept., 1931) the observations were made in a reading room, 24 x 15 x 8 ft, on the third floor of the building, having three large windows on a southwest wall and four doors. Two of the doors open onto a terrace, a third opens into a connecting room, and the fourth into a main corridor. The room is heated by two steam radiators, located under the windows and ventilated by opening windows and doors. Besides the observer there were usually one or two persons in the room when the measurements were made, and the occupants were at liberty to open or close the windows and doors and come and go as they pleased. An undesirable feature of this location was that the air in the room was at times vitiated by gases from laboratories across the hall. Some of the indoor readings were thus affected and had to be discarded.

From September, 1931 to May, 1933, the observations were continued in a smaller room, 10 x 12 x 12 ft on the second floor under more or less controlled conditions. This room has two windows on a southeast wall and one door. It is used solely by the observer as an office and observation room. There are no laboratories on this floor, but in order to guard against the possibility of vitiation from a classroom diagonally across the hall, the door of the observation room was kept shut. The air conditions in the room were controlled by opening or shutting the windows and radiator valve so as to suit the comfort of the observer.

Specifications of Ion Counters

The apparatus used for counting the number of small ions per cubic centimeter of air has been described in a previous paper[1], and a drawing of it is shown in Fig. 1. Following are specifications of the instruments which were not given in the earlier report.

The electrometers were specially made, double-fiber, portable, Wulf type, capable of measuring a maximum potential of 100 volts. In order to minimize electrical

*Assistant Professor of Industrial Hygiene, Harvard School of Public Health.

†Technician, Department of Industrial Hygiene.

[1]Yaglou, C. P., Benjamin, L. C., and Choate, S. P. Changes in Ionic Content of Air in Occupied Rooms Ventilated by Natural and Mechanical Methods. A. S. H. V. E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, 1931, *10*, 865.

[2]Ault, J. P., and Mauchly, S. L.: Atmospheric Electric Results Obtained Aboard the Carnegie, 1915-1921. *Publication No. 175*, 1926, *5*, 195. Carnegie Institute, Washington, D. C.

[3]Nolan, J. J., and Nolan, P. J.: Observations on Atmospheric Ionization at Glencree, County Wicklow. *Proc. Royal Irish Academy*, 1931, *40*, section A, No. 2.

For presentation at the 40th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, New York, N. Y., February, 1934.

leakage and polarization, a metal guard ring was cast in the amber insulation disc, and the ring was charged to the same potential as the collecting electrode by means of a changing plunger (see Fig. 1). The sensitivity of the instruments was between 1 and 2 divisions per volt, and they could be easily read to one-tenth of a division or less, with a magnification power of about 100. The normal charge applied to the system was 92 volts (2 radio *B* batteries) and the normal airflow (measured by means of a calibrated orifice meter) was 143 liters per minute. Since the effective length of the collecting electrode was 37 cm and the condenser outer tube 3 cm in diameter, theoretically the ions caught had mobilities greater than 0.2 cm per sec and per volt per centimeter.

All data presented herein refer to this particular group of small ions.

Method of Making Observations

Fig. 2 shows the arrangement used for drawing samples of outdoor air through the counters without having to take the instruments out into the open. Outdoor air was circulated through a 6-in. galvanized iron duct, the two ends of which projected to the exterior through boards fitted in the window openings. The inlet of the duct (lower end) was 38 ft above ground in the observations made on the third floor, and 22 ft in those taken on the second floor. In cold weather the air circulated by gravity and the temperature of the sample was kept close to 70 F (room temperature) by means of an electric heater at the base of the sampling duct. In warm weather circulation was effected by means of a suction fan.

Simultaneous ion counts in the air stream inside the duct, and on the terrace, under a tent, at a point about 6 in. from the inlet to the duct, showed no appreciable difference in the results. Similar tests with the electric heater on and off showed no apparent effect.

It is believed that the upper end of the sampling duct was sufficiently protected by the walls and eaves of the building against possible direct action of the earth's field, known as *electrode action.*[4]

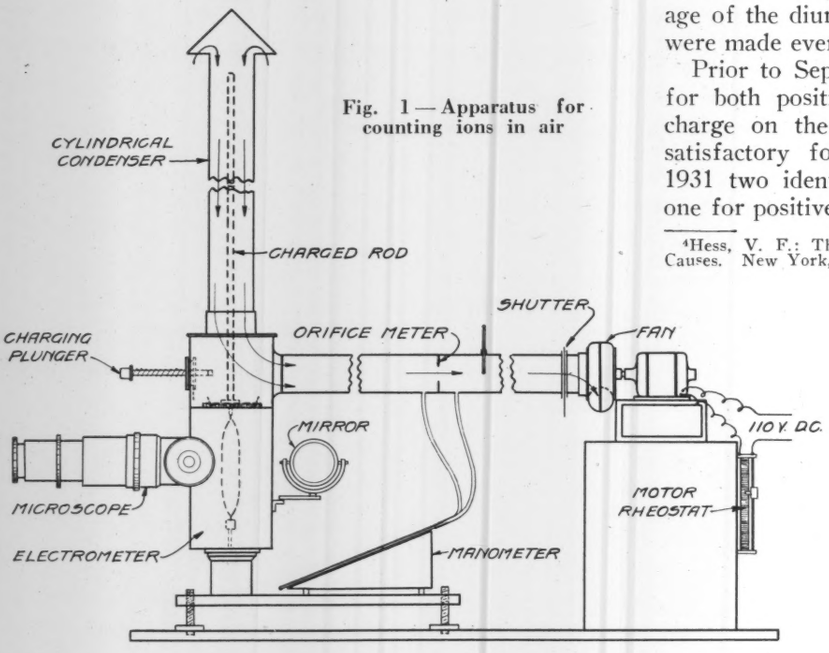


Fig. 1 — Apparatus for counting ions in air

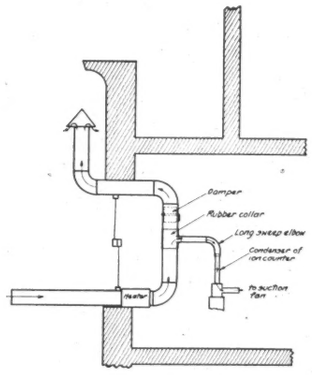


Fig. 2—Method of passing outdoor air through ion counter

Samples of outdoor air were passed through the counter by connecting the upper end of the condenser tube to the sampling duct with a long-sweep elbow (see Fig. 2). Originally the elbow was made of glass tube and it proved perfectly satisfactory, but after a year it was found that in very cold and dry weather, the glass adsorbed some of the ions passing through it. It was therefore, replaced with a brass elbow which gave satisfactory results regardless of humidity or temperature. An attempt was made to establish by special tests correction factors for the adsorption at various humidities, but no exact relationship could be found. Fortunately this error did not affect the indoor readings because the elbow had to be removed for drawing room air through the counter.

Systematic counts of small ions were made daily (Sundays and principal holidays excluded) from May, 1930 to May, 1933, at the hours 9:00-11:00 a. m. (75th meridian time), 1:30-2:00 p. m., and 4:30-5:00 p. m. for the ionization outdoors and at 9:00-10:00 a. m. and 2:00-2:30 p. m. for the ionization indoors. These hours were chosen from studies of diurnal variations so as to make the average of the three day-time readings (two for indoor air) approximately equal to the 24-hr average of the diurnal variation tests, in which observations were made every hour.

Prior to September, 1931, a single counter was used for both positive and negative ions, by reversing the charge on the collecting electrode. This proved unsatisfactory for many reasons and since September, 1931 two identical counters were used simultaneously, one for positive and one for negative ions, keeping them

[4]Hess, V. F.: The Electrical Conductivity of the Atmosphere and its Causes. New York, D. Van Nostrand & Co., 1928.

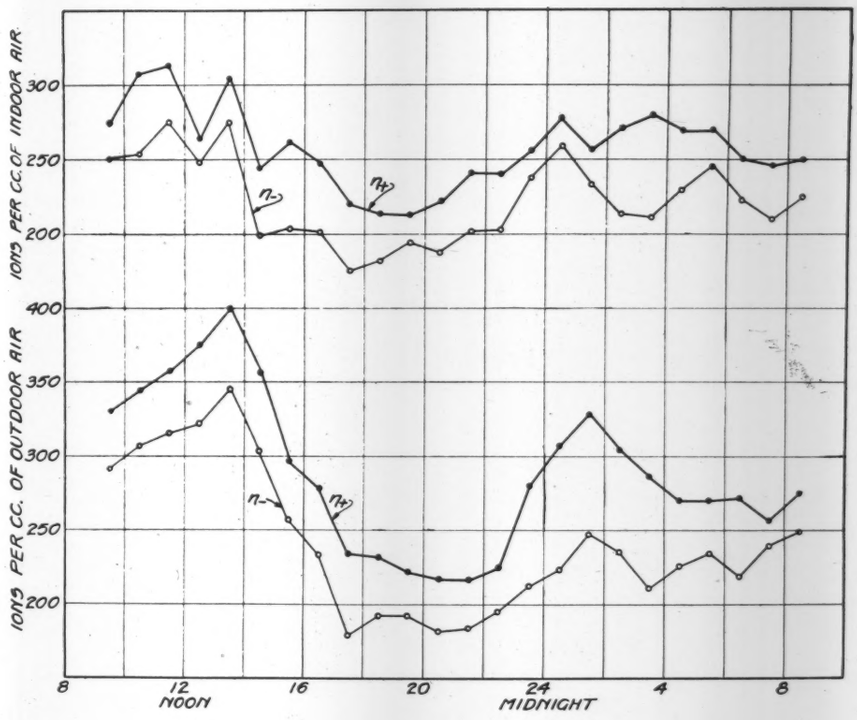


Fig. 3—Diurnal variation in the small-ion content of outdoor and indoor air in clear weather, Boston, Mass., seventy-fifth meridian time

always charged with the same polarity. Before beginning observations the instruments were allowed to run for about five minutes until a steady state was reached. Each observation took five minutes. As a rule, two or three 5-min readings gave a good average, but in changeable weather more readings were necessary.

Owing to the low voltage charge (92 volts), the guard ring in the insulation, and the artificial heating of air in damp weather, the insulation leakage was nil except in unusually warm and rainy weather when it was determined and the correction, if any, applied to the readings.

In addition to a standard group of small ions (mobility upward of 0.2 cm per second per volt per centimeter) parallel counts were made of the so-called *molecular* ions[4], having mobilities of 1 cm per second per volt per centimeter or higher, and from time to time counts were made of a broader group of ions, down to 0.03 cm per second per volt per centimeter mobility, by utilizing Ebert's standard ion counter. These observations were made for the purpose of estimating the extent to which *molecular* and intermediate ions were present in indoor and outdoor air. They will be presented in another paper.

Diurnal Variation in the Small-ion Content of the Atmosphere

Studies of complete diurnal variation in the small-ion concentration of outdoor and indoor air were carried out once each season during 1930 and 1931, and once every month in 1932 and 1933. In this series of tests, observations were made every hour or oftener, beginning at 9:00 a. m. (75th meridian time) and continuing over a period of 24 hours or longer. In order to avoid the disturbing influence of clouds, rain, snow, etc., tests were run in clear weather only. There were, however, several experiments in which unexpected cloudiness, rain, or snow near the middle or end of the run made the results unsuitable for the purpose. Omitting all such tests and all observations with the glass elbow, there remain thirteen good 24-hour experiments to be considered here, spread over the period of December, 1931, to May, 1933.

The hourly means of all thirteen diurnal variations runs are plotted in Fig. 3. The curves for outdoor air show two peaks and two valleys. The peaks occur shortly after mid-day and mid-night; the valleys between 6 and 10 p. m. and 4 and 8 a. m. These characteristics persist more or less, in the individual runs and

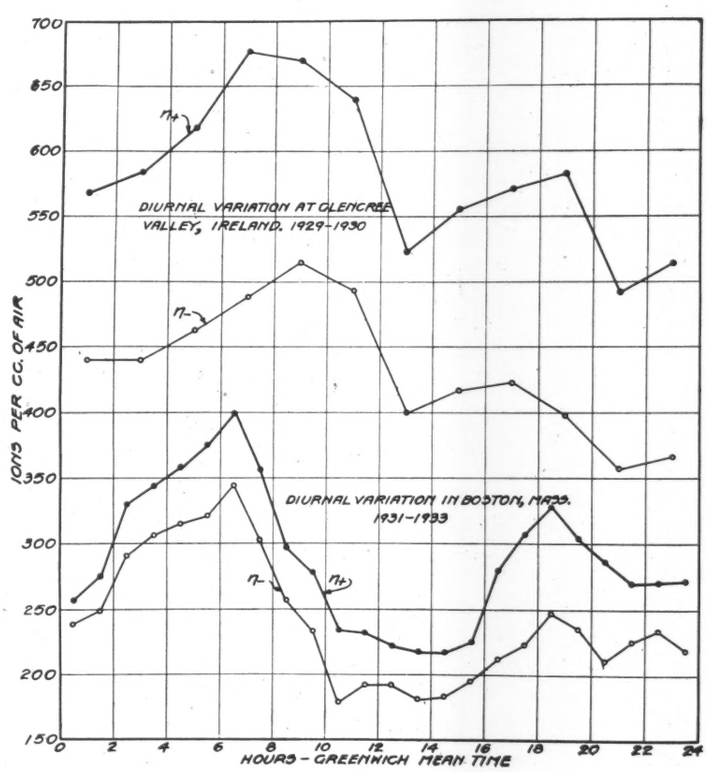


Fig. 4—Comparison of diurnal variation in Boston, Mass., with that at Glencree Valley, Ireland, as reported by Nolan & Nolan[3]

in the averages by season, the main difference being that the actual concentration of ions is higher somewhat in summer than in winter.

In indoor air the diurnal changes in ionization are less pronounced than in outdoor air (see Fig. 3), both the amplitude of variation and the actual ion content being lower. During the hours of maximum ionization the concentration of ions indoors (in a room occupied by one person) is about 20 per cent lower than that outdoors while during the hours of minimum ionization, there is practically no difference.

If the curves for outdoor air are plotted to Greenwich mean time as in Fig. 4, a fairly good agreement appears to exist between the ionization in Boston and that at Glencree Valley, Ireland, as reported by Nolan and Nolan[3]. Not only the curves are similar in shape but the maxima and minima occur at approximately the same universal time. This supports the prevailing belief that the sun is not a sufficient nor an important direct cause of atmospheric ionization, since both at Glencree Valley and Boston the maxima and minima appear to occur at practically the same universal time in spite of the fact that there is a difference of about five hours between the local times of the two places. In other words, while the ionization in Boston is found to be somewhat higher during the day than during the night, at Glencree Valley the reverse holds true.

The difference between the concentration of ions at Glencree Valley and Boston is probably real, and may be ascribed to differences in topography and air pollution. By contrast with the thickly settled community of Boston, Glencree Valley is thinly populated, and direct contamination from chimneys and automobile exhausts is small. Observations made by us in country places within 25 miles of Boston gave results comparable or even higher than those of Glencree Valley.

Seasonal Variation

The monthly daily average small-ion content of air shown in Fig. 5 was computed from the three daily sets of readings taken in the forenoon, early afternoon, and early evening. Each point on the curves represents the mean of between 22 and 28 daily averages; each daily average is in turn the mean of three sets of readings (two for indoor air), each set consisting of two or more ion counts. The data include all day-time observations made at the specified hours, except those vitiated by smoke (nine sets altogether), and those affected by heavy rains (15 sets) to such an extent as to show concentrations of 500 or more ions per cubic centimeter of air.

The curves for each of the three years agree well among themselves in showing distinct minima during the winter months and maxima during the summer months. The dotted section of the curves for the winter of 1930-31 represents doubtful data owing to a probable adsorption of ions by the glass elbow. The winter of 1930-1931 was the coldest and that of 1932-33 the warmest of the three, but all three winters were considerably milder than the average for Boston. Therefore the winter results may not be representative of normal weather for the locality.

Under the conditions which existed in the observation room, namely with the observer alone in the room, and no smoking, the mean seasonal curves for outdoor and indoor air (Fig. 5) do not differ radically except in the amplitude of variation from winter to summer. Omitting values for the winter of 1930-31, the ionization during the winter and spring of 1932 and 1933 appears to be lower indoors than out-of-doors; in the autumn season the difference becomes less noticeable whereas in the summer the ionization indoors is on the whole higher than that outdoors.

These differences may be ascribed partly to changes

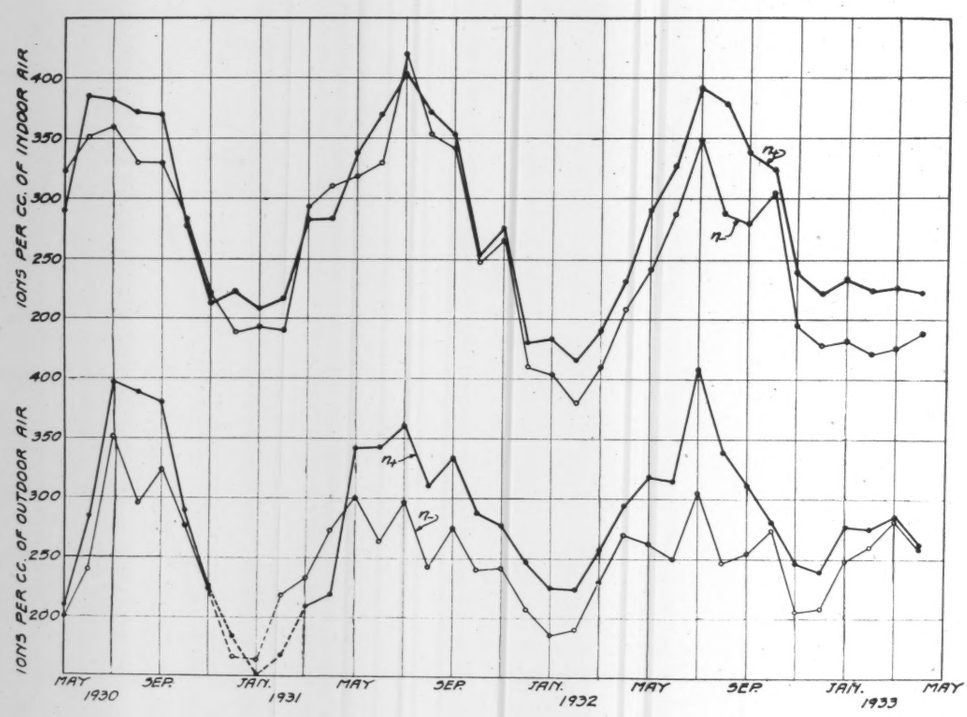


Fig. 5—Seasonal variation in the small-ion content of outdoor and indoor air, Boston, Mass.

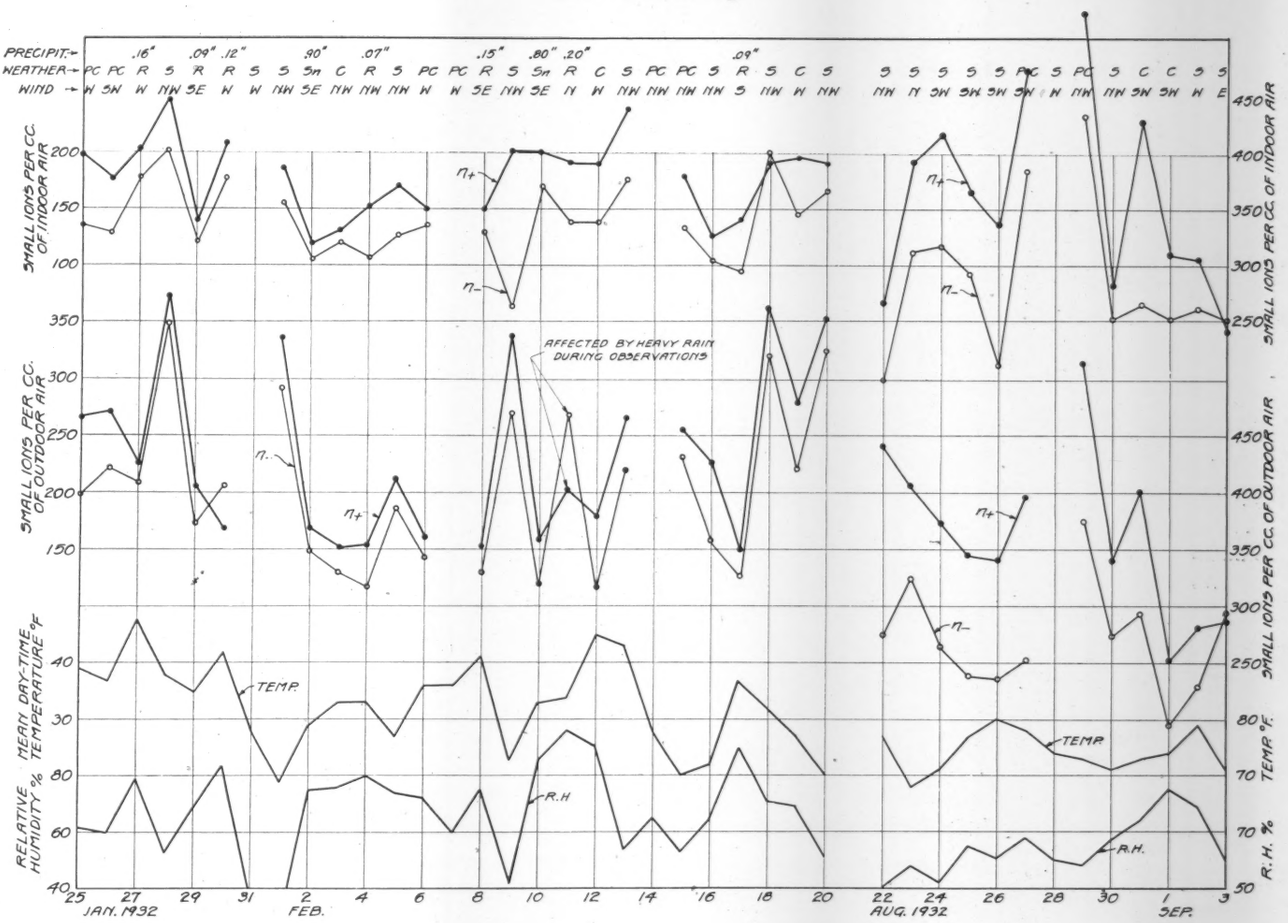


Fig. 6—Interdiurnal changes in temperature and humidity in relation to changes in the small-ion content of outdoor and indoor air

Legend: Precipitation: 8 a. m. to 8 p. m. Weather: *s*, clear; *pc.*, partly cloudy; *c*, cloudy; *r*, rain; *sn*, snow. Wind: N, north; E, east; S, south, W, west.

in weather and partly to seasonal changes in the ventilation rate of the room. In addition there seem to be other unknown factors which affect considerably the indoor ions in summer.

In winter when the windows of the observation room were mostly shut, marked changes in outdoor ionization were accompanied with comparatively small changes indoors (see Fig. 6).

In summer such contrasts did not usually occur, and the full range of outdoor changes in ionization was realized indoors (Fig. 6), except under certain conditions of humidity, cloudiness, and rain (dealt with further on) which produced a distinct lowering in the outdoor concentration of small ions without affecting appreciably the concentration indoors. Even in clear summer weather the small-ion content of indoor air was often higher than that of outdoor air. On the other hand, the *molecular* ions, which are most sensitive of all ions to changes in air conditions, were at all seasons less numerous in indoor than in outdoor air.

The only data available for comparison of the seasonal variation curves for outdoor air are certain observations[5] of the Carnegie Institution of Washington made over a period of four months, December, 1915 to March, 1916, during the cruises of the *Carnegie* in the Pacific, Atlantic, and Indian Oceans. Minimum ionization for these three months occurred in January as in our observations, but Wait[6] does not believe that the data over the sea are sufficient to warrant any conclusions.

The Glencree Valley observations are not, according to Nolan and Nolan,[3] well enough distributed over the 12 months of the year to conclude whether there is any annual variation in the ionization.

Variation with Temperature and Humidity

It is generally believed that there is a direct relationship between temperature and atmospheric ionization, the connection being sometimes attributed to an ionizing influence of the sun. Table 1 presents the results of an examination for possible association with temperature and humidity at like seasons. In order to preclude any possible unbalance in the data, all readings taken by the use of the glass elbow (those prior to May, 1931) were rejected. Likewise the observations made on days with precipitation of 0.01 in. or more between 8 a. m. and 8 p. m., were excluded. The figures in the brackets shown in Table 1 represent the number of daily averages from which the mean ion numbers were derived.

For temperatures under 70 F a rise in temperature appears to be associated with an increase in the ion numbers at all seasons and all percentages of relative humidity (Table 1). However, this direct association does

[5]Bauer, L. A., and Swann, W. F.: Results of Atmospheric Electric Observations Made Aboard the Galilee (1907-1908) and *Publication No. 175, Vol. 3*, Carnegie (1909-1916). Carnegie Institute, Washington, D. C.

[6]Wait, G. R.: Variations in the Small-ion Content of the Atmosphere and Their Causes. *Journal Franklin Institute*, 1933, *216*, 147.

Table 1—Daily Average Small-Ion Content of Outdoor Air in Relation to Temperature and Humidity May, 1931 to May, 1933. Boston, Mass.

Excluding days with precipitation of 0.01 in. or more
(Figures in brackets represent number of days)

Mean Daytime Temperature F	Winter								Spring							
	Average Relative Humidity, Per Cent								Average Relative Humidity, Per Cent							
	35 or Less		36–55		56–75		76–100		35 or Less		36–55		56–75		76–100	
	n+	n−	n+	n−	n+	n−	n+	n−	n+	n−	n+	n−	n+	n−	n+	n−
Under 32	323	289 (9)	288	254 (15)	265	232 (9)	179	150 (2)								
32–50			335	305 (13)	268	231 (36)	177	146 (7)	496	489 (3)	321	294 (15)	280	256 (15)	216	181 (7)
51–70					304	256 (4)	240	180 (1)	297	243 (5)	386	349 (24)	318	276 (16)	259	228 (5)
71 and over									470	373 (2)	351	263 (9)	414	305 (3)		
	Summer								Autumn							
Under 32											278	238 (5)	251	222 (5)		
32–50			440	356 (12)	353	276 (27)	256	206 (7)	277	240 (2)	316	280 (17)	263	214 (26)	206	168 (6)
51–70			403	285 (32)	334	238 (30)	262	231 (6)			347	289 (11)	322	281 (30)	263	232 (11)
71 and over													307	220 (2)	356	299 (2)

not hold for temperatures over 70 F. The numerous observations in the summer season indicate a decrease in ionization when the temperature exceeds 70 F.

More definite than the effect of temperature is the inverse relationship between humidity and ionization (Table 1). With a rising humidity, the concentration of ions decreases consistently at all temperatures and seasons. The decrease seems to be largely a pure humidity effect as in about two-thirds of the cases it was not associated with cloudiness on the day of observations nor with rain or cloudiness within 24 hours following the observations.

So far as temperature and humidity are concerned, low concentrations of small ions appear to occur in moist air at temperatures under 50 F. (Table 1). The minimum concentrations fall in winter. High ion concentrations may occur at any temperature so long as the humidity is well under 75 per cent. The most frequent occurrence is in the summer when the temperature is between 60 and 70 F and the relative humidity between 35 and 55 per cent.

Much more important than either temperature or humidity appear to be the interdiurnal *changes* in temperature and humidity which in the absence of serious disturbances by rains or other causes are usually accompanied with inverse changes in ionization. Illustrations for winter and summer appear in Fig. 6. The temperature and humidity values shown are daytime averages corresponding to the time at which the ion counts were made. It makes no difference if the 24 hour averages are used instead. The breaks in the ionization curves occur on Sundays when no observations were made. It can be seen that a significant rise in the interdiurnal temperature or humidity is as a rule preceded or accompanied with a falling ion content but if the temperature continues to rise for three days or more, the ionization begins to increase.

Reversely when the temperature or humidity falls, the small-ion content of air usually increases on the day of fall or on the preceding day, but if the fall continues for three days or more, the ionization begins to decrease. With few exceptions these changes persist regardless of actual temperature level, and it seems to make little difference whether the rise or drop of temperature brings pleasant or unpleasant weather.

In winter a decrease in the small-ion content can be more directly associated with approaching rain or snow storms than with a rise in temperature and humidity which usually precede such storms. Conversely, an increase in the ionization may be ascribed to the advent of clear weather, rather than to a drop in temperature and humidity at the end of a storm. In summer however, when storms occur much less frequently, the factor of precipitation does not seem to offer a satisfactory explanation for the inverse relationship between changes in temperature and humidity and changes in ionization. The data shown in Fig. 6 will bear out these statements.

The foregoing alterations in the small-ion content of the atmosphere are not entirely confined to outdoor air as they also affect the indoor air (Fig. 6) much more in the summer than in the winter as explained earlier.

Influence of Cloudiness and Precipitation on the Small-ion Content of the Atmosphere

Small patchy clouds, other than those associated with precipitation, do not in general produce conspicuous effects on the small-ion content of air. On the other hand, the great majority of clouds which cover the sky wholly or partly, diminish considerably the ion concentration, as shown in Table 2. The effect is largely confined to outdoor air, except in overcast weather which eventually lowers the indoor concentration to that outdoors.

Light or moderate precipitation of all kinds produces a significant reduction in the small-ion numbers at all seasons (Table 2). Heavy precipitation results in a considerable increase of the number of negative ions which may be explained by the well-known Lenard[4] effect (p. 63). The increase appears to be much greater during showers and electrical storms than during steady rains, and it is least conspicuous in heavy rains of winter.

During a local thunderstorm in which heavy rain was accompanied with almost continuous thunder and lightning for about 20 minutes, the number of both positive and negative ions increased enormously, reaching peak values of 3000 and 3150 ions per cubic centimeter respectively at the height of the storm. The average values during the 20-minute period were 1342 and 1465 for the positive and negative ions, as shown in Table 2. Despite this enormous increase in the outdoor concentration, the indoor concentration was but slightly increased.

The influence of precipitation on the small-ion content of indoor air depended a great deal upon the duration and character of the precipitation and to a small extent upon the direction of the wind. Light and moderate

Table 2—Effect of Cloudiness and Precipitation on the Small-Ion Content of Outdoor Air May, 1931 to May, 1933. Boston, Mass.

**Excluding days with precipitation of 0.01 in. or more*

Character of Days	Winter				Spring				Summer				Autumn			
	n+	n−	n+/n−	No. of Days	n+	n−	n+/n−	No. of Days	n+	n−	n+/n−	No. of Days	n+	n−	n+/n−	No. of Days
Clear days*	310	276	1.18	55	373	308	1.16	64	379	286	1.39	67	316	268	1.22	55
Partly cloudy*	260	226	1.22	27	282	248	1.18	30	350	272	1.31	38	302	260	1.21	32
Cloudy*	188	143	1.25	14	207	181	1.19	10	288	230	1.35	9	241	201	1.22	30
Character of Precipitation	**n+**	**n−**	**n+/n−**	**Sets of Observations**	**n+**	**n−**	**n+/n−**	**Sets of Observations**	**n+**	**n−**	**n+/n−**	**Sets of Observations**	**n+**	**n−**	**n+/n−**	**Sets of Observations**
Fog	195	155	1.25	3	138	144	0.98	3	162	68	2.38	1	213	146	1.46	2
Light rain	190	176	1.10	18	173	154	1.19	22	297	226	1.33	7	187	166	1.20	18
Moderate rain	195	224	0.92	24	193	208	1.00	7	150	143	1.24	2	202	223	0.97	16
†Heavy Rain	205	254	0.89	4	342	574	0.70	7	366	547	0.66	7	487	1032	0.47	7
Heavy rain with thunder					1342	1465	0.92	1								
Snow					181	173	1.04	2								
Heavy snow	291	325	0.89	1												

†No thunder.

precipitation of a few hours' duration did not as a rule affect appreciably the concentration of ions indoors. As a result the indoor air was richer in small ions than that outdoors before and during precipitation of such character, especially in the summer.

Likewise heavy showers failed to produce indoors the conspicuous increase in the number of negative ions noted out-of-doors, although in some instances there was a definite increase.

Persistent rain or snow tended to equalize the concentration of small ions in outdoor and indoor air. Wind blowing against the window openings of the observation room had a similar tendency, but the response was usually slow and gradual. A much more prompt response resulted when a current of outdoor air was blown into the room by means of a fan on the window sill. As soon as the room dry- and wet-bulb temperatures approached the outdoor values, the concentration of ions indoors fell substantially to the prevailing outdoor values.

Variation with Barometric Pressure and Wind

Referring to Table 3, a rise in the barometric pressure appears to be associated with a decrease in the outdoor ion count, but the range of variation is not great. An effect of this kind is to be expected if the ionization in the atmosphere near the surface of the earth is derived mainly from emanation of radio-active substances in the soil (60 per cent of it, according to Millikan[7]). A lowering of the pressure would cause soil air rich in emanation to be drawn up through the capillaries of the earth into the atmosphere, whereas a rising pressure would impede diffusion of this highly ionized air into the atmosphere above.

It is of interest to note that when the results are arranged according to temperature and barometric pressure, as in Table 3, the apparent connection between actual temperature and ionization observed in Table 1 is practically eliminated.

The variation with wind direction is shown in Table 4. The highest ionization values were obtained with winds from the West and Northwest, and the lowest with those from the Northeast and East. For the locality of Boston, West and Northwest winds usually bring clear weather, sharp drops in temperature, and comparatively low relative humidities. All of these conditions were shown to be associated with high concentrations of small ions. On the other hand, winds from the East and Northeast bring overcast weather, and they are largely responsible for the storms of winter. As a rule they are preceded by a rise of both temperature and humidity, culminating in rain or snow. These adverse conditions find a powerful reflection in the small-ion content of outdoor air as has been seen.

[7]Millikan, R. A.: On the Question of the Constancy of the Cosmic Radiation and the Relation of These Rays to Meteorology. *Physical Rev.*, 1930, *36*, 1595.

Table 3—Variation of Daily Average Small-Ion Content of Outdoor Air With Barometric Pressure May, 1931 to May, 1933. Boston, Mass.

Excluding days with precipitation of 0.01 in. or more
(Figures in brackets represent number of days)

Mean Daytime Temperature F	Winter								Spring							
	Average Barometric Pressure, In. Hg								Average Barometric Pressure, In. Hg							
	29.75 or Less		29.76–30.00		30.01–30.25		30.26 and Over		29.75 or Less		29.76–30.00		30.01–30.25		30.26 and Over	
	n+	n−	n+	n−	n+	n−	n+	n−	n+	n−	n+	n−	n+	n−	n+	n−
Under 32	293	269 (8)	286	252 (8)	303	274 (9)	264	216 (10)								
32–50	316	292 (8)	281	239 (18)	276	245 (18)	221	196 (12)	323	294 (6)	353	331 (11)	270	249 (16)	269	227 (7)
51–70	308	265 (2)	187	137 (1)	327	269 (2)			393	382 (5)	350	310 (19)	342	297 (23)	216	165 (3)
71 and over									431	326 (1)	328	237 (6)	420	325 (7)		
All temperatures	304	279 (18)	279	243 (27)	288	251 (29)	241	206 (22)	361	333 (12)	347	304 (36)	325	284 (46)	253	214 (10)
	Summer								Autumn							
Under 32									268	277 (1)	220	177 (2)	202	211 (1)	289	243 (6)
32–50									347	274 (2)	302	255 (11)	299	254 (17)	232	197 (21)
51–70	362	287 (7)	402	332 (18)	321	248 (16)	332	240 (5)	304	265 (4)	372	328 (14)	285	241 (26)	320	274 (8)
71 and over	379	286 (8)	370	272 (46)	315	223 (13)	320	213 (1)			301	210 (1)	342	276 (3)		
All temperatures	371	286 (15)	379	289 (64)	318	236 (29)	330	236 (6)	311	269 (7)	330	284 (28)	292	248 (47)	262	222 (35)

Table 4—Variation of Daily Average Small-Ion Content of Outdoor Air With Prevailing Wind Direction May, 1931 to May, 1933. Boston, Mass.

(Excluding days with precipitation of 0.01 in. or more)

Prevailing Wind	Winter			Spring			Summer			Autumn		
	n+	n−	No. of Days	n+	n−	No. of Days	n+	n−	No. of Days	n+	n−	No. of Days
N	188	145	7	191	159	1	370	279	3	247	210	6
NE & E	224	186	3	226	188	16	265	214	14	262	219	6
SE & S				320	275	8	342	258	18	255	238	9
SW	229	195	16	292	247	19	298	214	24	268	219	28
W	291	245	25	365	322	26	390	301	17	308	266	31
NW	306	272	45	380	341	34	429	326	38	316	280	37

Winds from other directions (North, South, Southeast and Southwest), when not accompanied by precipitation, give intermediate values between the maxima and minima, depending largely upon the humidity, cloudiness, and upon the drop or rise in temperature and humidity which accompany the wind.

The influence of wind direction upon the indoor concentration of ions is likewise an indirect one, associated with temperature and humidity changes, cloudiness, and precipitation, etc. which may or may not affect appreciably the indoor ions, as pointed out earlier.

Concerning wind velocity, the results are not very definite. With increasing force of wind from the West and Northwest, the concentration of outdoor ions is somewhat increased, owing perhaps to the drawing of strongly ionized air from the capillaries of the soil by the aspirating action of wind. Winds from the North, South, Southeast, and Southwest fail to show such an effect, while with winds from the East and Northeast the concentration of ions appears to decrease with increasing wind velocity.

A de-ionizing action with increasing force of winds from the East and Northeast is perfectly feasible when the ground is wet, as water in itself is an excellent ion trap, and the higher the wind velocity, the greater the diffusion of atmospheric ions to the water.

Summary and Conclusions

Daily observations of the small-ion content of outdoor and indoor air from May, 1930 to May, 1933, disclose definite diurnal and seasonal variations depending largely upon local and general meteorological conditions.

The most important climatic factors affecting the small-ion content of outdoor air appear to be the interdiurnal changes of temperature and humidity. A drop in the interdiurnal temperature and humidity is as a rule preceded or accompanied with a sharp rise in the ion content of air, and vice versa, provided that the drop or rise in temperature and humidity does not continue more than two days.

Cloudiness, high humidities, and light or moderate precipitation of any kind have a detrimental effect on the small-ion content of outdoor air. Heavy precipitation results in a considerable increase in the number of small negative ions, and when the precipitation is accompanied with thunder and lightning both positive and negative ions attain very high values.

In the locality of Boston, high concentrations of small ions are as a rule associated with winds from the W. and N. W., which usually bring sharp drops in the interdiurnal temperature and humidity and clear weather. The actual temperature and barometric pressure are not very important so long as the relative humidity is well under 75 per cent.

Low concentrations of small ions are generally associated with stormy winds from the E. and N. E., which are often preceded with a rise of temperature and humidity finally culminating in rain or snow. The minima occur in damp or moist weather when the temperature is under 50 F.

In winter, the concentration of small ions in indoor air is considerably lower than that in outdoor air. In summer the reverse seems to hold true. Adverse weather of short duration does not conspicuously affect the indoor concentration in spite of powerful effects on the outdoor ions. Persistent bad weather tends to equalize the outdoor and indoor ion numbers.

In the light of the present study it would seem that the small ion content of the atmosphere is an important meteorological factor which deserves wider recognition and more study than heretofore afforded to it.

Acknowledgment

The authors are greatly indebted to Sarah P. Choate and Allan D. Brandt of the Department of Industrial Hygiene for their valuable assistance in carrying out special observations.

Twenty Years with Chicago School System

John Howatt, chief engineer of the Chicago Public School System, completed 20 years service with the Board of Education in December and 40 members of his staff celebrated the event by tendering a luncheon to Mr. and Mrs. Howatt at the Hotel Sherman.

Previous to his connection with the Chicago schools, Mr. Howatt was in the government service as supervising engineer in the middle western territory.

N.R.A. Codes

In December, General Hugh S. Johnson, National Recovery Administrator, announced the appointment of government representatives to 90 code authorities, among which were the following: *Asbestos*—George S. Brady; *Automatic Sprinkler*—Ralph J. Fogg; *Boiler Manufacturing*—Neal W. Foster; *Gas Appliances and Apparatus*—H. M. Halsted, Jr.; *Heat Exchange*—Neal W. Foster; *Oil Burner Industry*—R. B. Paddock, Lauren E. Seeley, Harold Sweatt and Harry F. Tapp; *Pipe Nipple Manufacturing*—William Lawson; *Pump Manufacturing*—Neal W. Foster; and *Steel Tubular and Firebox Boiler*—Neal W. Foster.

The boiler manufacturing industry submitted amendments and a supplement to the Code of Fair Competition for the Boiler Manufacturing Industry at a public hearing on Wednesday, December 27, at Washington, D. C.

Public hearings were held by Deputy Administrator B. W. Murray on December 28 at the Hotel Mayflower in Washington, D. C., sponsored by the *Concealed Heater Manufacturers Association, Industrial Unit Heater Association,* and *National Association of Fan Manufacturers.*

Low-Cost Air Conditioning for a Small Residence

By **M. K. Drewry,**[1] **Milwaukee, Wis.**

(NON-MEMBER)

THE modification of a warm-air system for hot-water air heating, tap-water cooling, automatic fuel feed, and year-round air filtration and humidity control has afforded the experiences and data recorded herein. The eight points of greatest interest are: (1) 90 per cent average boiler efficiency, (2) $6 per summer tap-water cooling, (3) year-round coke fire, (4) 8.5 unit heat transfer rate from a 167-sq ft automotive-type radiator of 1 cu ft volume but adequate for heating and cooling 17,000 cu ft space, (5) 10 per cent CO_2 average from coke fire, (6) 160 F average flue gas temperature, (7) 70 watts input for supplementary mechanical air circulation, and (8) satisfactory stoking by gravity of small-size fuel from a simple welded hopper. Total investment and annual operating costs, including cooling, were found to be no greater than those of the previous simple heating system.

The Installation

Figs. 1 and 2 show the equipment which was used. On February 18, 1933, it replaced a standard warm-air furnace in a 17,000-cu ft residence at Milwaukee, Wis., utilizing the same air circulating system as did the original furnace (Figs. 3, 4, and 5). That this heating system is a combination warm-air and hot-water system, employing water as a heat-transfer medium between the fuel-combustion process and the air-heating procedure, is apparent. A small hot-water boiler (18 in. firepot) provides heated water to an automotive-type radiator mounted in a separate casing through which the room-air circulates. Fuel is fed into the boiler by gravity from a welded sheet metal hopper.

For moderate rates of heat output to the rooms, the air flow is induced by natural convection. When a greater heat output is required, either in cold weather or during rapid room heating, the propeller-type fan comes into service. The fan starts automatically when the water temperature at the top of the boiler approaches the boiling point.

A thermostat in the rooms regulates the heat output and a damper regulator located on the boiler serves to start and stop the fan and to limit the heat output of the fire from exceeding the capacity of the radiator. Thus, operation of the unit is automatic, except for filling the fuel hopper and shaking ashes once daily for the average heating demand per day.

Summer operation for cooling consists of admitting tap-water to the heat-exchanger and operating the fan continuously to supply cooled air to each room through the riser pipes and the same registers as are employed for heating. The hot-water boiler is isolated from the radiator throughout the summer by closing gate valves, and is then employed only to heat service water. Because of the low heating requirements of service water, fuel additions are made only once weekly during the summer.

Design

To accomplish the main object of providing acceptable year-round automatic air conditioning without exceeding warm-air furnace costs required consideration of many combinations of equipment. Application of rapidly-advancing power plant practices and principles assisted materially. Making dual or treble use of apparatus, working each piece of equipment to maximum capacity and efficiency, and utilizing standard products as much as possible, helped to attain the desired result. Automotive-type radiation, because of its extremely high heat-transfer efficiency, low cost, small space requirements, and simple pipe connections, could be used because low water pressure could be employed and deterioration prevented by attention to boiler-water conditioning. High reliability and adequate free air-flow area past its blades when idle prompted choice of a propeller-type fan.

Hopper fuel supply permitted choice of a small boiler with adequate small grate area for high efficiency at average ratings, yet ability to carry peaks, and with ability to maintain extremely low heat outputs satisfactorily for mild weather space heating and for service-water heating in summer. Flue gas temperatures were maintained low without additional expense by utilizing the smoke pipe as an air heater by making it air tight and locating the check door in the chimney. The temperature drop in the smoke pipe equals 300 deg at maximum output.

Propeller fan and motor tests, combined with calculations of piping resistances deduced from circulating air temperatures with the warm-air furnace operating, disclosed that adequate circulation could be obtained with a 1/20 hp motor using only 70 watts. The size of the humidity pan was calculated from a simple test of evaporation rate from an open, heated dish. Table 7 summarizes the principal design data for all of the major apparatus.

[1]Asst. Chief Engr. of Power Plants, Milwaukee Electric Railway & Light Co.

For presentation at the 40th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, New York, N. Y., February, 1934.

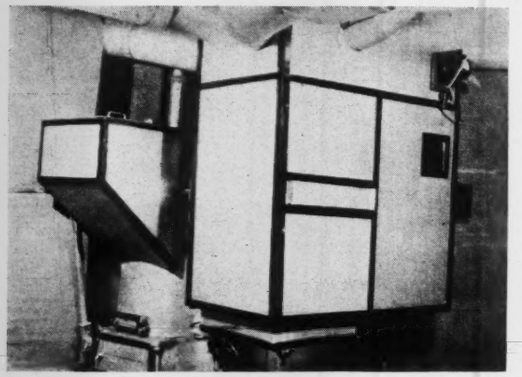


Fig. 1—The year-round air conditioning unit installed in 1933

marize the daily data collected during March and April and Fig. 7 shows room and heated-air temperatures on the coldest day experienced. Fig. 8 shows boiler test data when thermostatically controlled to average about 25 per cent output.

Operating Experiences

Room temperature regulation: A lesser vertical temperature gradient in the rooms was readily noticeable after installation of the new system; and temperatures were more uniform in horizontal planes, as well. Where 75 F, as registered by a centrally-located thermometer, caused discomfort with the previous installation, the same temperature was nearly acceptable because of better vertical and horizontal uniformity of air temperature. Another proof of this uniformity is the fact that the centrally-located thermostat in an unheated hall consistently checks the fire within two or three minutes after the fan starts. Many charts were secured showing no more than 2 F maximum variation of average room temperature. (See Fig. 7.) Air issues from the wall registers at about a 45 deg angle when the fan operates, instead of rising almost vertically when in-

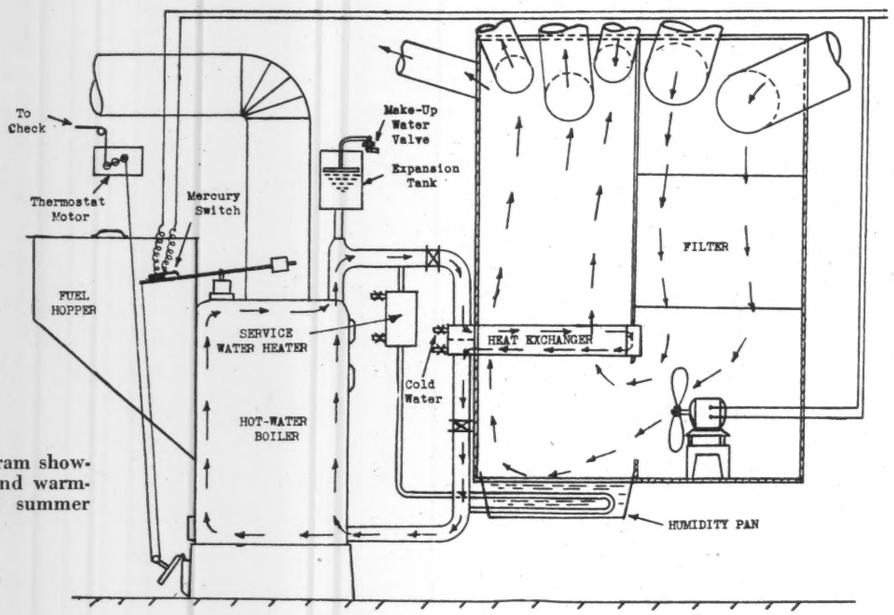


Fig. 2—Air conditioner diagram showing combination hot-water and warm-air system for winter and summer service

Preliminary Tests

Early in February the hot-water boiler, casing, and radiator of the new installation were assembled near the furnace, a smoke pipe connection was provided to the chimney, and preliminary tests were made. Data showed that the unit would furnish 90,000 Btu per hour, which was the desired output. On one occasion it was brought from cold, starting the fire with kindling wood, to 90,000 Btu per hour, in only 23 min. This experience proved the value of the small water storage (160 lb) in the system. Operating experiences, with the unit serving for typical residence duty during the subsequent heating months and cooling months, were observed and recorded in detail as material for an engineering thesis† on which this paper is based. Enough data were collected to approximate efficiency and capacity reliably each day for two heating months. More detailed data were taken during three shorter tests to learn the characteristics over a wide range of ratings. All test procedure followed accepted methods as far as conditions permitted. Air flow was measured with a calibrated anemometer and the thermometers were checked. Tables 1 and 2 sum-

†University of Wisconsin, 1933.

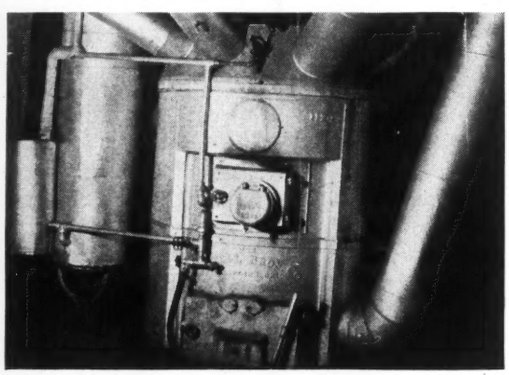


Fig. 3—The warm-air furnace as originally installed

duced by natural convection as was the case with the original furnace. The velocity is not objectionable, rather it is desirable for inducing liberal air movement.

Fan noise: Though the fan and motor were quieter than average portable room ventilating fans when tested outside of the casing, their noise was not acceptable when confined in the casing and released through the tin leader pipes into the rooms. Wall-board had been used for the casing to diminish the sounds, but not until the casing was lined with ⅜ in. of hair felt was the problem acceptably solved. The sound can now be likened to that of a quiet oil burner in a warm-air furnace. Since it is of relatively low frequency, its total elimination by absorption is difficult.

Ashes and clinkering: Experience showed that "slicing" the ash bed, by means of a ⅜-in. rod inserted through a hole in the clinker door, reduced the combustible in the ash from 8 per cent to 5 per cent and

Fig. 4—The Milwaukee residence which is air conditioned

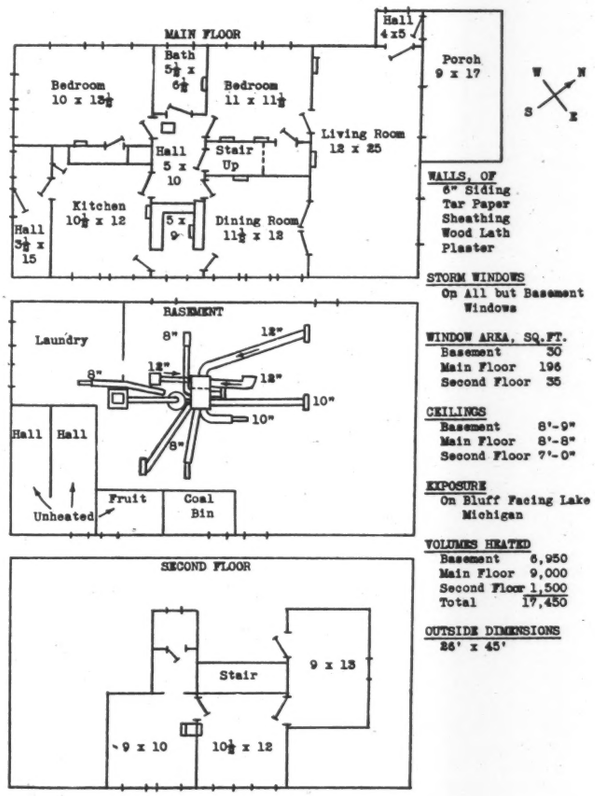


Fig. 5—Residence floor plans

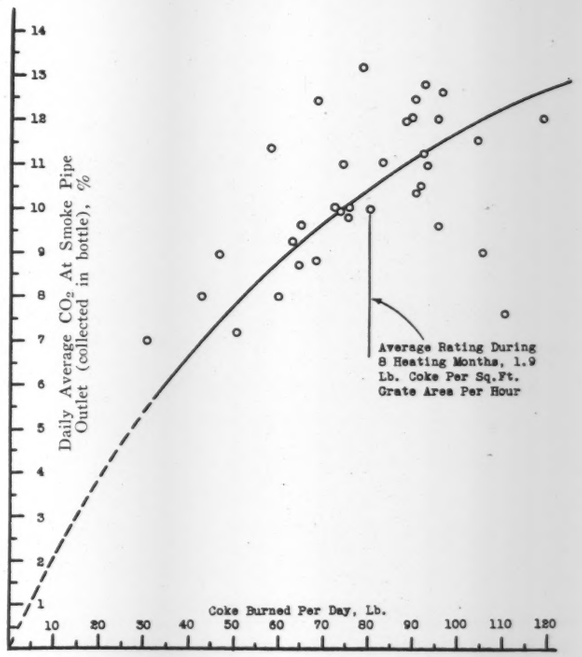

Daily Average CO_2 At Smoke Pipe Outlet (collected in bottle), %
Average Rating During 8 Heating Months, 1.9 Lb. Coke Per Sq.Ft. Grate Area Per Hour
Coke Burned Per Day, Lb.
10 20 30 40 50 60 70 80 90 100 110 120

Fig. 6—CO_2 in flue gas versus coke burned per day

improved the CO_2. If this was done before shaking, and shaking discontinued when bright coals appeared in the ash pit, downward ash flow was continuous and the firebed was kept in a stable condition.

A second type of coke clinkered more readily than the first kind, though all clinkers were small and were readily broken by slicing to pass through the grates without any trouble. After a capacity test of 10 hours at continuous maximum rating with the less favorable coke, clinkering was no different than normal. The same coke, when hand fired, often formed large clinkers that

Table 1—Summary of March and April Operating Data

Averages of Daily Readings

Month	March	April
Coke burned, lb	111	73
Ashes removed, lb	8.6	4.8
Humidity water evaporated, lb	39	28.8
Energy used by fan, kwh	0.66	0.3
Number of thermostat operations	26.5	20
Flue gas analysis		
CO_2	9.0	10
O_2		10.15
CO		0.20
Relative humidity in rooms, %	43	49
Outdoor temperature, degrees Fahr	32.7	43.8

Table 2—Coke and Ash Accounting

Coke Delivery No.	1	2	3
Date first used	Feb. 21	Mar. 16	Apr. 8
Lb coke, as fired	2,417	2,345	1,925
Moisture, per cent			
As received		21.5	10.0
Last fired		13.0	5.0
Average	17*	17.0	7.5
Lb coke, dry	2,000	1,950	1,780
Ash			
By analysis, dry, per cent	9.5	9.5*	6.7
Refuse			
Lb, dry	202	155	121.5
Per cent combustible, dry	8.2	6.2	7.4
Ash only, lb	185	145	113
Ash only, per cent of coke	9.25	7.4	6.3
Difference, analysis versus ash weight, % of coal weight	+0.25	+2.1	+0.4

*Assumed.

filled the entire firepot. It appears that the continuous gravity feed eliminates localized high temperatures attendant on periodic hand firing.

Ashes removed checked very closely with weights calculated from the coke analyses. For the first ton, the disparity was only 3 per cent. (See Table 3.)

CO experiences: CO was first detected in the flue gas after the coke hopper nearly emptied on one occasion and considerable green coke was put onto the fire when re-charging the hopper. The rapid evolution of CO forced flue gas from a leak in the smoke pipe, and long bluish-white flames were observed through the cleanout doors, passing entirely through the boiler into the smoke pipe. Orsat readings taken at 5-min intervals showed about 16 per cent CO_2 and the following percentages of CO: 5, 3, 2.6, and 3.4. In 30 min about one per cent CO was averaged. Twelve hours later some was still detected, and the average for the 24 hours was 0.4 per cent.

This experience proved that the phenomenon of CO_2 reduction to CO occurs in a thick incandescent fuel bed. Unless air is supplied over the fire, appreciable losses occur, since one per cent CO represents about 5 per cent fuel loss. To supply over-fire air continuously is an undesirable corrective, for it can readily cause greater sensible heat loss in the flue gases than it saves in reducing CO losses. Continuous fuel feed onto a thin fuel bed is the best solution.

The continuously high combustion rate during the 10-hour capacity test caused the formation of 2.6 per cent CO after 1½ hours of test. It was necessary to admit air above the fire to eliminate this loss. Since continuously high ratings are so seldom carried for periods longer than an hour, the annual loss from this cause is slight. It does indicate one limitation of combustion rate in the installation, however.

Table 3—Coke Analyses

Coke Delivery No.	1	3
Producer	Gas Company	Coke Company
Volatile matter, %	4.88	1.27
Fixed carbon, %	85.62	92.03
Ash, %	9.5	6.7
Sulphur, %	0.81	
Btu per lb, as received	10,400	11,700
Btu per lb, dry	13,255	13,000
Btu per ton delivered, million	24.7	22.5
Cost per ton	$8.50	$9.50
Cost per million Btu, cents	34.4	42.2

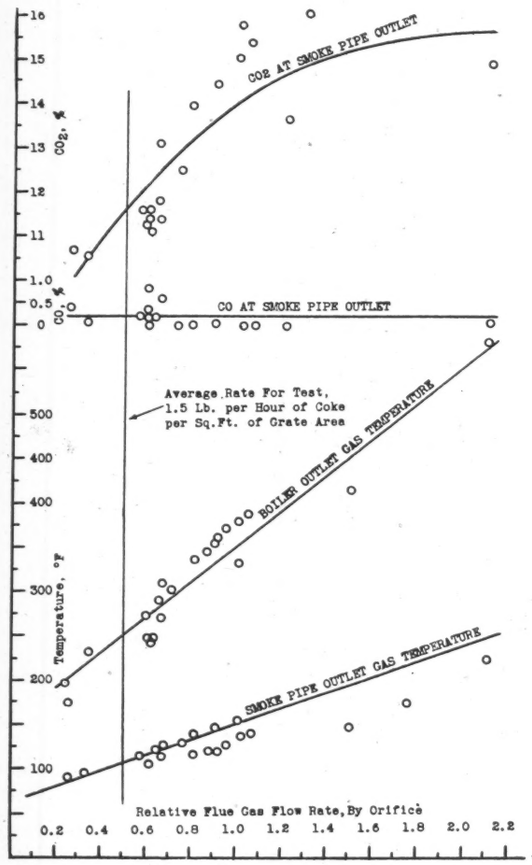

CO2 AT SMOKE PIPE OUTLET
CO AT SMOKE PIPE OUTLET
Average Rate For Test, 1.5 Lb. per Hour of Coke per Sq.Ft. of Grate Area
BOILER OUTLET GAS TEMPERATURE
SMOKE PIPE OUTLET GAS TEMPERATURE
CO2, %
CO, %
Temperature, °F
Relative Flue Gas Flow Rate, By Orifice
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2

Fig. 8—Service test of small hot-water boiler

Outdoor temperature 45 F. Boiler cleaned before test. Efficiency, crediting radiation losses, in excess of 90 per cent.

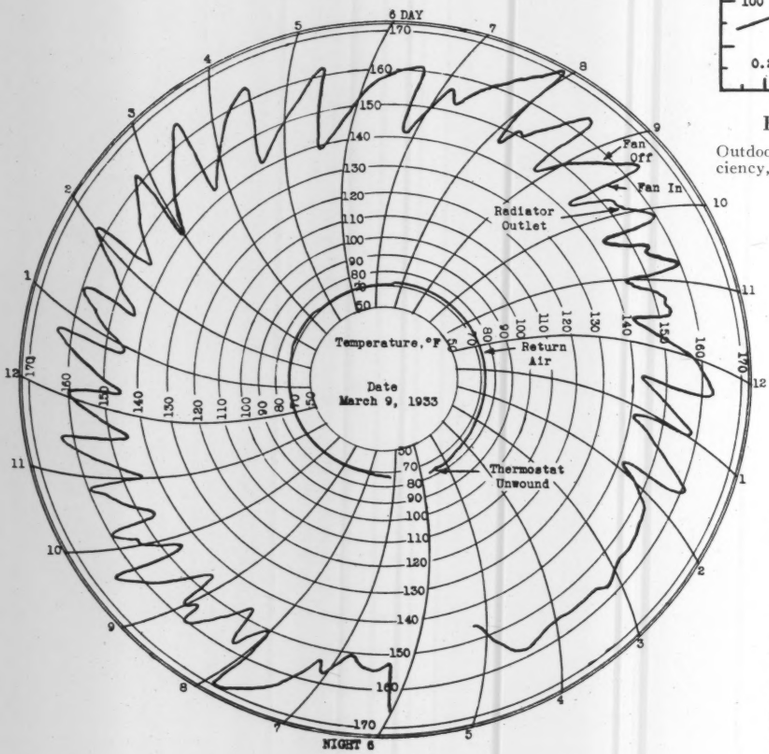


Fig. 7 — Chart of the coldest day's results

+5 F and a 30 mile per hour northwest wind most nearly taxed the capacity of the apparatus. Note uniform return air temperature, which is a good index of average room temperature. The thermostat operated 49 times on this day.

Re-charging an empty hopper on another occasion caused two "puffs" which lifted the hopper cover slightly for pressure relief. Unless over-fire air was admitted after hand charging the previous warm-air furnace, this trouble would occur quite consistently.

Hopper performance: Burning-back of the fuel into the hopper positively never occurred. In fact, inspections generally showed no incandescent fuel near the boiler opening, and in most cases only the more distant half of the fuel bed was afire. Air-tightness of the hopper was undoubtedly responsible. Leakage into the hopper through its cover was observed to cause an appreciable increase in excess air and tightness caused as high as 14 per cent CO_2 flue gas to be present above the fuel in the hopper. Drying of the fuel caused condensation of water vapor on the walls of the hopper, which finally caused undetected caking and temporary failure of the gravity feed principle. Removal of the caked fuel, and monthly cleaning, prevented further trouble.

Boiler water control: On several occasions of rapidly increasing ratings, steam was formed in the boiler and released to the room through the vent provided. Evidence of expansion-tank water spillage onto the basement floor told what had happened. The water-temperature regulator has a thermal lag, but succeeds in adequately checking the fire without permitting steam-binding of the radiator or any interference with automatic operation. The float-operated make-up valve automatically replenished the lost water.

Several dissolved-oxygen measurements of the boiler water showed that it contained only one per cent as much oxygen as tap water (0.05 cc per liter versus 6.0 cc per liter). At all times the boiler-water is crystal clear, which indicates an absence of corrosion. Under these conditions, the thin copper tubes of the automotive radiator are expected to last indefinitely, and never to become clogged with sediment.

Year-round fire maintenance: Service-water heating during summer months not only affords inexpensive hot water but it eliminates the need of starting several fires each year for mild weather comfort. On two occasions, one in June and one in September, cooling and heating were needed and actually used in reverse sequence to the seasonal trend. Storage of heat in the boiler water affords an instantaneous space-heating supply. Cooling and heating operations can be alternated in a minute at any time simply by operating three valves and starting or stopping the fan. Morning "chill" can be dispelled immediately, and without causing temperature over-runs.

Anthracite coal of buckwheat size was used satisfactorily for a week of service-water heating, but was discontinued because of its greater dustiness than coke. Pea-size anthracite burned satisfactorily for mild-weather heating. It is improbable that the combustibility of the larger sizes of anthracite is sufficiently high to maintain combustion over long periods at the very low rate required for service-water heating.

Smoke pipe CO_2 readings when using coke fuel for service-water heating averaged above 5 per cent, and the smoke pipe outlet appeared at room temperature to the touch. To furnish a continuous supply of service water for four individuals, at an average temperature of about 135 F, 450 lb of coke, costing $1.50, was burned per month. The year-round hot water cost will average less than $1.00 per month, for the boiler radiation losses are rightfully charged to space heating for 8 heating months.

Humidity conditions: Though measurements showed about only 45 per cent average relative humidity a higher moisture content of room air would have been undesirable. Moisture collecting on the inside of storm windows during relatively warm weather indicated that similar wetness inside building walls might be anticipated in colder weather. Storm windows, though equipped with gaskets to make them relatively air-tight, frosted very considerably during the coldest weather. Previous experience with high humidity suggests that the present amount will cause condensation on some internal walls during zero weather. This indicates that the present equipment has adequate capacity. Tables 1 and 2 show the quantities of water evaporated per day. To accomplish this, 4.5 per cent of the fuel consumed on an average heating season day was required for evaporating the humidity water and 80 lb of fuel was burned on the average day, and 31 lb of water evaporated. Initial charging of the humidity pan with a small amount of chemicals prevented scale formation and corrosion.

Discussion of Special Test Results

Capacity: The unit operated 10 hours at an average heat output from the radiator slightly in excess of 100,000 Btu per hour. During this time it controlled itself automatically, and the boiler water temperature averaged 206 F. (See Table 4 and Fig. 9.)

The other two special tests were performed at approximately 25 per cent and 50 per cent of maximum capacity. During these tests the boiler was controlled by the room thermostat, which operated the drafts about hourly. As a result, boiler rating varied over wide limits throughout the tests, thus simulating actual operation. The fan was kept running constantly for the purpose of measuring air flow and heat output more accurately.

Radiator performance: A unit-heat-transfer rate of 8.5 Btu per hour per sq ft per deg F, nearly 6 times the 1.5 rate of cast-iron hot-water radiators, was obtained from the radiator during the capacity test. Counterflow design, and adequately high air velocity, made this high value possible. A 167-sq ft radiator costing only $26 was made to do the work of 650 sq ft of standard radiators costing $150 without piping.

McAdam's *Heat Transfer,* p. 226, affords a means of predicting automotive-radiator performance which agrees fairly well with the results obtained.

Efficiency: These special tests support the continuous operating data in indicating an average operating efficiency during the heating season of at least 90 per cent. CO_2 averages 10.5 per cent (see Fig. 6), and the accompanying flue-gas temperature at the smoke-pipe outlet is 160 F. Combustible in the ash averages 6.5 per cent, or about ½ per cent of the fuel. Reference to Fig. 9 shows efficiencies calculated from heat balance data over the range of loads; figured on the basis of total heat output to the radiator, humidity pan, and water heater, and on the second basis of total heat output including boiler radiation and smoke-pipe heat supply to the basement. The latter efficiencies are reported because the basement requires heating, since the air-flow casing and

leader pipes have but slight heat loss. The former efficiencies were figured to permit comparison with measured efficiencies.

Measured efficiencies were higher in every case than heat-balance calculations indicated might be attained because of uncontrollable differences in unconsumed fuel in the boiler at the starting and stopping of tests. Because of the nature of the installation, starting from cold and quenching at the end of each test was not practical and would not represent true operating conditions. Power plant experience has indicated the heat balance method entirely reliable, especially when low losses occur, as in this case. The measured efficiencies are not reliable even though a special effort was made to obtain accurate input and output measurements during the maximum capacity test. The measured efficiency is about 10 per cent too high.

It is interesting to note that only a 9 F temperature drop was averaged between the radiator outlet and the registers during the capacity test. This shows the value of forced circulation for high outputs and proves the need of boiler and smoke-pipe heat losses to heat the basement adequately. Study of the heat balance data will show an analysis of the various losses and their magnitude. Coke is conducive of high boiler efficiency because of its low hydrogen loss.

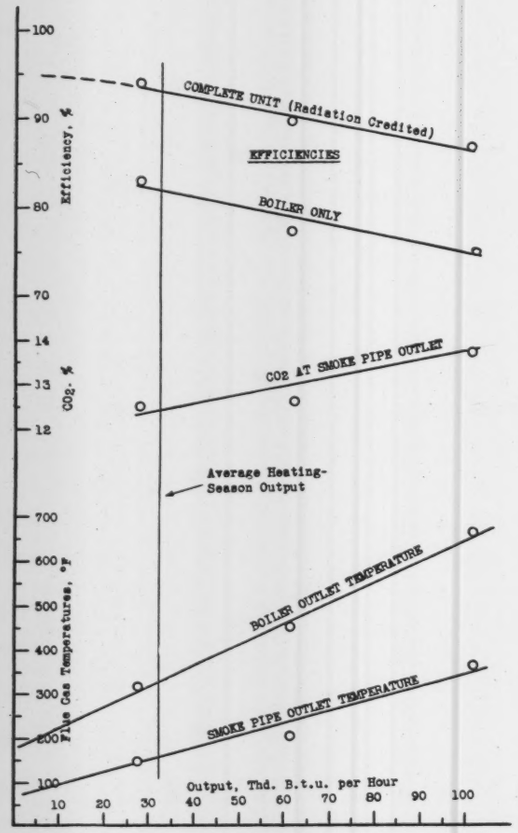


Fig. 9—Results of special tests

Tests made with off-and-on thermostatic control during regular, typical residence service, are closely indicative of annual results. Because of low heat losses from the air conditioner, basement heating is required, and the upper efficiency line applies.

Table 4—Special Tests

Capacity, Approximate, %	25	50	100
General			
Date, 1933	March 26	March 19	April 9
Duration, hours	8	10	10
Outdoor temperature	45	26	40
Temperatures			
Air heated			
Radiator outlet	98	136	168
Radiator inlet	69	72	72
Radiator rise	29	64	96
Flue gases			
Boiler outlet	320	451	667
Smoke-pipe outlet	128	202	361
Boiler water			
Radiator inlet, average	142	172	206
Radiator outlet, average			177
Service water heater			
Inlet			206
Outlet			189
Service water			
Outlet			125
Inlet			108
Basement temperature	66	64	
Flue Gas Analyses			
CO_2	12.5	12.6	13.7
O_2	8.25		6.6
CO	0.15		0.3
Total Quantities, Lb			
Humidity water evaporated			26
Fuel used	21.5	49	109
Refuse			
Per cent combustible	7.33	6.2	5.25
Air Flow			
Cfm above radiator	935	935	1175
Cfm at registers			1291
Cfm average			1233
Fuel			
Total fired, lb	21.5	49	109
Lb per hour	2.69	4.9	10.9
Analyses			
Fixed carbon, %			92.03
Ash, %			6.7
Moisture, %	15	18.0	8.0
Btu per lb, as fired	10,600	11,000	11,900
Btu per hour fired	28,500	54,000	128,500
Heat Output, Btu per Hour			
By radiator	27,800	61,500	102,000
At registers			101,000
To heat service water	1,000	1,500	2,000
To evaporate humidity water	1,000	1,500	2,700
Total, at radiator	29,800	64,500	106,700
Total, at registers			105,700
Heat Balance and Efficiency Data			
Boiler only			
Losses, due to			
Moisture in fuel	1.1	2.1	0.93
Hydrogen (1%)	1.0	1.04	0.99
Dry flue gas	10.2	15.50	18.5
Moisture in air	0.15	0.25	0.35
CO	1.0	1.5	2.1
Combustible in refuse	0.5	0.5	0.41
Radiation	3.1	1.9	1.5
Total	17.1	22.8	24.8
Calculated efficiency, %	82.9	77.2	75.2
Boiler and Smoke Pipe			
Losses, due to			
Moisture in fuel	1.0	1.9	0.80
Hydrogen (1%)	0.9	0.95	0.85
Dry flue gas	2.4	5.4	9.1
Moisture in air	0.05	0.12	0.17
CO	1.0	1.5	2.1
Combustible in refuse	0.5	0.5	0.41
Radiation (Useful)	0	0	0
Total	6.0	10.4	13.4
Calculated efficiency, %	94.0	89.6	86.6

Cooling Experiences

Occurrence of 101 F weather in June emphasized the comforts of residence cooling. Absence of awnings and tree shade, and continuance of the warm period for several days, afforded an adequate test of the cooling cycle. Early-morning room temperatures of 78 F rose to 81 F by evening when water-flow was not allowed to exceed 1,000 lb per hour (0.9¢ per hour). Later experience proved that greater water flow improved the radiator performance more than expected, and 79 F room temperature was later maintained positively constant on a bright 95 F (maximum) day with 60 F inlet water. The outside temperatures cited are those of the local weather bureau. Occupancy consisted of two adults and two children. A cooling capacity of 12,000 Btu per hour was proved to be as adequate as a 75,000 Btu per hour heating capacity. This experience indicates that

Table 5—Cooling Tests

(June 7 and 8, 1933)

Time	Air Temperatures, Degrees Fahr: Outside SW	Outside NE	Outside SE	Rooms: Living	Rooms: Hall	Radiator Out.	Basement	Attic	Water Temp. Out	Water Temp. In	Lb Condensate	Meter Readings: Water Cu Ft	Meter Readings: Electrical Kwh
6/7/33													
AM 7:00	79		79	77	76.5	66	72		66	54			
7:30	80			77.5	76	66	71.5	81	66	55		846.5	37.7
8:00	81			77.5	76	65	71.5					853	
10:00				77.5	76.5	65	71		66	55		884	
PM 12:30	88			78	76.5	65	70.5		66	53		910	
1:00	93			78	76.5	65	70.5	95	63	53			
5:30	100	91		81	79	64	71	102	62	52		966	
7:45	80	81		81	80	62	71	92	64	51		1012	
9:30										51		1029	38.6
6/8/33													
AM 7:00	77		79	78.5	76	66	70.5		65	54		1120	39.4
PM 1:00	90		92	80.5	78	63.5	71	100	63	52		1125	39.8
6:00		86	82	81		63	72	96	63	52		1318	
7:30												1328	40.2
Total 36.5 hr.											75	525.7	2.5
Ave. 1 hr.	85	86	84	79	77.5	64.5	71	95	64.4	53	2	900	70

Units	Lb	Lb	Watts
Cost per hr, ¢		0.81	0.21
Total, ¢		31	7.5
per day, ¢		15.5	3.8
per day, water and electricity, ¢		19.3	

Summary of Cooling Tests

June 7 and 8, 1933

Humidity Results		
Dehumidification, lb per hr, average	2	
6/7/33, 5:30 PM		
Temperatures, degrees Fahr	Inside	Outside
Wet bulb	72.5	81
Dry bulb	79.5	91
Per cent relative humidity	73	66
Moisture content, grains per lb air	112	148
Relative moisture content, %	75	100
Cooling Results		
Duration of continuous test, hr	36.5	
Average outside air temperature, degrees Fahr	85	
Average inside air temperature, degrees Fahr	78	
Average temperature difference, degrees Fahr	7	
Maximum outside temp., deg Fahr (Weather Bureau)	94*	
Maximum temperature difference, deg Fahr	16	
Water flow, lb per hr	900	
Electricity used, watts	70	
Average cost per hr, total	1¢	

*82% sunshine on June 7, 99% on June 8.

cooling calculations for the residence concerned can be made with the same heat-per-degree-Fahrenheit as employed for heating, and that 10 F average cooling is an adequate allowance. Table 5 shows typical cooling data for two days in June.

An effective temperature of 75.5 was maintained as a daily average throughout the summer with tap water from 50 F to 60 F. The A. S. H. V. E. Guide indicates 75 deg as the upper boundary for the Summer Comfort Zone.

Thermal storage of the residence structure acts as a relatively large flywheel to assist the performance of a cooling unit. The previously mentioned 3 F rise during the hottest day was entirely acceptable, and was regained before the next morning by continued operation of the unit throughout the night at reduced rating, though the night was relatively warm. Approximate calculations of the heat-storage capacity involved accounted for the result, and indicates the practicability of almost entirely neglecting sun effect in installations where cooling equipment is rather expensive. In this particular case, the radiator could be made twice as large at relatively little expense, and high water flow could be employed to obtain ideal results, but the actual results obtained were satisfactory.

Dehumidification did not afford the 50 per cent relative humidity median suggested by Comfort Chart in The Guide for 70 per cent was averaged. On one 36-hour run, 2 lb per hour of condensation was collected, and inside air averaged three-fourths the water-vapor content of outside air. Water velocity through the radiator affected condensation rate appreciably. Drainage of condensation from the closely-spaced fins and tubes was satisfactory, though about one-sixth of the openings were stopped by droplets. Best radiator performance was 10 per cent below its unit heat transfer of 8.5 Btu per hour per square foot per degree Fahrenheit when heating. Approximately 5 per cent reduction was expected because of the lower fluid temperatures. Condensation heat transfer would have been a net gain had not some of the air passages clogged.

Room air seemed much like the enjoyable "fresh" air from Lake Michigan, or like that during a cool evening or after a rain, all of which are high in humidity. With adequate cooling, filtration and circulation, 70 per cent humidity in air may be more acceptable than 50 per cent humid air. At least, it is more typical of average summer air.

Thermostatic control of the cooling cycle did not prove desirable because of the need of previously closing all windows and doors when morning temperatures indicated that a warm day was in prospect. Automatic control would create much extra operating cost unless assisted intelligently. There is no need of modulating control during the day, for room temperatures change very slowly. Again, structural thermal capacity is important. Cooling and heating duty can be likened to relative motive requirements for marine and automotive duty, respectively. Residence cooling equipment can be "base-load," this experience indicates.

All registers were used for cooling without change. Return air averaged 2 F lower than air at the breathing level, and 3½ F difference existed from floor to ceiling. Register velocity of 400 ft per minute caused the cooled air to ascend to the breathing level at about 45 deg angle, after which it descended. Its velocity could readily be noticed at lower levels across the 12-ft to 14-ft rooms. This experience of cooled air falling was found to be of great assistance in cooling an auditorium during the past summer. Discarding of cooling water onto the residence lawn proved a practical and desirable procedure. Irrigation requirements were not exceeded during the 312 hours of cooling found necessary. Table 6 summarizes cooling data for the summer.

Considering the extremely acceptable relief the cooling equipment afforded at the modest operating cost of 1.27¢ per hour and nearly negligible investment cost, the sys-

Table 6—Summer Cooling Data and Costs

Month	June	July	August	Sept.	All
Hours of cooling	186	88	16	22	312
Cooling water, cu ft	2,793	1,671	340	495	5,299
Cooling water, lb per hr	940	1,190	1,330	1,390	1,060
Cooling cost, $	1.68	1.00	0.20	0.30	3.18*
Cooling cost, ¢ per hr	1	1.1	1.25	1.35	1.02
Electricity, 26 kwh at 3¢					$0.78
Total cooling cost for summer					$3.96
Total cost per hour					$0.0127
Estimated total cost for normal summer					$6.00

*$5.84 was total billed for period of May 12 to September 26, 8,900 cu ft at 6¢ per 100 cu ft plus 50¢ service charge. 4,900 cu ft was used the previous summer.

Table 7—Capacity and Design Data of Equipment

BOILER: Cast iron, round sectional, 280 sq ft 8-hr rating, 825 sq ft rated capacity, 18 in. diameter. 1.76 sq ft grate. 48 in. high, 22 in. outside diameter. Approximately 18.75 sq ft heating surface. Water capacity 90 lb. Total weight, 700 lb.

Covering: ¾ in. plastic cement having 0.8 Btu per hour per sq ft per degree Fahrenheit per 1 in. conductivity, painted aluminum bronze.

Grates: ⅛ in. opening, 3 in number.

SMOKE PIPE: 9 in. diameter, 10 ft long, air-tight 24-gage sheet metal, painted black.

RADIATOR: 20½ in. × 23⅜ in., automotive-type, fin and tube, 167 sq ft.

Fins: 6 per inch, 3⅝ in. × 23½ in., 0.005 in. thick, 140 total.

Tubes: ⅛ in. × ¾ in., 0.008 in. thick. $\frac{7}{16}$ in. spacing, 4 rows deep, 2 per pass, 184 total tubes.

Water boxes: 18 gage brass. Inlet water box has internal baffle. 2-in. standard pipe connections.

2.25 sq ft air flow area, 5.9 sq in. water flow area per pass. 26 per cent direct surface, 74 per cent finned surface.

MOTOR: 1/20-horsepower, 1140 rpm, 110 volts, unit heater type. Totally enclosed, wick oiling, 57 per cent efficiency, 55 per cent power factor, 1.07 amps, 65 watts at full load. Rubber mounting.

FAN: 4 blade 16-in. propeller type.

FILTER: 4-20 in. x 20 in. x 2 in. oiled glass-wool units in parallel.

HUMIDITY PAN: 6 in. x 20 in. x 20 in., 12-gage sheet pan. 2—16-in. lengths of 1-in. pipe and return bend for heating coil.

LEADER PIPES: 2.5 sq ft flow area, composed of 34 ft of 8-in. pipe and 15 ft of 10-in. pipe.

COLD AIR RETURN PIPES: 2.35 sq ft air flow area, composed of 21 ft of 12-in. pipe.

FUEL HOPPER: 4.6 cu ft, 125 lb normal charge.

AIR FLOW CASING: 2 ft x 4 ft x 5 ft high outside. Wall-board on 2-in. x 2-in. pine frame. Painted aluminum bronze. Lined with ⅜ in. of felt.

THERMOSTAT: Spring motor. 50 operations per winding. Operates on bell transformer.

tem can certainly be considered a practical success under the particular local conditions prevailing in Milwaukee.

Records of tap-water temperatures at an outlying point in Madison, Wis., prove that results would be equally satisfactory in that city, which distributes 53 F well water at 1.2¢ per 1,000 lb. When studying tap water temperatures for cooling, it is extremely important that they be taken during periods of continued warm weather, when residential water use is high and distribution temperature rise is smallest. September cooling in Milwaukee was as satisfactory as in June, though the pumping station is 6 miles distant.

It is emphasized that these cooling results were obtained with an efficient, counterflow radiator and reasonably cool tap water. Careful attention to radiator design does much to make tap-water cooling acceptable. Air can be cooled within 5 F of the entering water temperature, and the outlet water temperature can be 5 F higher than the cooled air by proper design.

For the average summer in Milwaukee $6 summer cooling costs are estimated. Though June was 10 F warmer than ordinarily, July and August weather was favored with an unusual preponderance of winds from Lake Michigan which limited daytime temperatures, causing only $4 cooling cost. (See Table 6.) Milwaukee's incremental water and electricity costs of 6¢ per 100 cu ft and 3¢ per kwh are low, but doubling or trebling of the actual cooling costs would not make cooling impractical.

Total Annual Costs

Using data from the previously installed warm-air furnace and from the present installation, costs compare as follows:

Installation	Warm-Air Furnace	Air-Conditioning Unit
Initial cost, installed	$200.00	$250.00
Annual fixed charges, 12%	24.00	30.00
Operating Costs		
Heating		
Tons coal	10.0	8.5
Cost per ton, $	8.50	8.50
Coal cost, $	85.00	72.25
Electricity, 133 kwh at 3¢		4.00
Total cost, $	85.00	76.25
Cooling		
Water cost, $		4.85
Electricity cost, $		1.17
Total cost, $		6.02
Service water heating during summer (4 months)		
Gas cost, $0.75 per M, $	6.00	
Coke cost, $		4.00
Maintenance		
Annual average, $	15.00	5.00
Total annual operating and fixed charges	$130.00	$121.27

Better thermal economy and lesser maintenance of the newer unit more than pay its summer operating costs. The advantages of having year-round conditioned air, with less attendance, are incidental.

Conclusions

Design and actual operating data are included herein to show that satisfactory year-round air conditioning can be practiced under the particular existing conditions in Milwaukee at no greater total operating and investment cost than simple warm-air heating. High boiler efficiency, low cooling cost, and moderate equipment costs make this result possible.

Method of Choosing Location of, Financing and Conducting Meetings of the Society

Resolved: That inasmuch as the Annual and Semi-Annual Meetings of the Society come under the jurisdiction of the Council, the following rules governing the handling of such meetings, be adopted by the Council and published in the JOURNAL of the Society at least twice during every year, preferably just prior to each meeting:

1—The Council will select the city in which the Annual or Semi-Annual Meeting is to be held, giving due consideration to the invitations received from Chapters or members as well as to the advisability of so distributing those meetings as to make them of the greatest advantage to the general membership, and to reduce as far as possible the expense of members attending.

2—That an appropriation be made to cover the entertainment or local expenses, incurred in connection with the meeting not exceeding $500.00, the regular meeting expense to be taken care of by the General Fund of the Society in the regular way.

3—That no registration fee or compulsory obligations of any nature be imposed on members or guests.

4—That the purchase of tickets for banquets or for any other form of entertainment that may be provided be entirely voluntary.

5—That the grouping of features and the same of tickets for group features be discouraged.

6—That the raising of Funds from manufacturers of heating apparatus be discouraged.

7—That the display of samples, or of literature, advertising the product of any manufacturer in any way, shape or form, be not permitted at the booths, registration desk, or in or about the meetings.

8—That the distribution of trade papers be entirely at the discretion of the committee in charge.

9—That the local Chapter, or local members, be empowered to form a General Committee with such sub-committees as may be required to handle the details of transportation, hotel accommodations, entertainment, finance, etc., and that this General Committee be requested to confer frequently with the Council, through the Secretary of the Society, and to make frequent reports on progress in connection with the various matters being handled by them.

10—That the arrangements of elaborate and costly entertainment features be discouraged.

Adopted at Council Meeting, January 29, 1926.

The Cascades of the Hotel Biltmore, New York

New York Extends a Hearty Welcome

PLANS are well in hand for the Society's 40th Annual Meeting, which will be held in New York February 5 to 8, 1934 under the auspices of the New York Chapter. The Committee on Arrangements has announced that meeting headquarters will be at the Hotel Biltmore, where technical sessions will be held every day.

The Committee on Arrangements directed by Arthur Ritter is preparing for a big attendance and during the December Meeting of the New York Chapter he announced the program of social events. Registration will commence on the morning of February 5 on the 17th floor of the Hotel Biltmore and W. W. Timmis and his Reception Committee will be on hand to greet the visiting members. During the morning the Council Meeting will be held and at 2:00 p. m., Pres. W. T. Jones will call the First Session to order.

The Program Committee has selected a group of 18 papers for presentation, and discussion of these subjects should provide many enjoyable and educational hours.

The arrangements provide for time for the visiting members and ladies to see the sights of New York and to enjoy an adequate program of entertainment at nominal expense. On Monday evening, Alfred Engle will stage a supper and dance in the Casino Bleu, with a nationally known dance orchestra and a floor show of famous entertainers. This Get-Together Party will commence at 8:00 p. m. A nominal charge will be made and tickets should be secured at the time of registration.

The ladies' events have been planned to give them leisure for shopping and other diversions. A bridge and tea will be held at the Biltmore on Tuesday at 2:30 p. m. and the visiting ladies will be chaperoned by Charles S. Hoffman and Clyde R. Place. On Wednesday evening at 7:30 p. m. the Annual Banquet and Dance will be held in the ballroom of the Hotel Biltmore. This will be the outstanding social event of the meeting. Immediately after the service of dinner, a brief program, which will include the presentation of the past president's medal, will be conducted by W. H. Driscoll, toastmaster. Dancing will be enjoyed until 1 o'clock. The Committee in charge is H. B. Hedges, Walter Heibel, A. J. Offner and E. J. Ritchie. Tickets will be available at the registration desk and tables will seat 8 or 10 persons. Early reservations should be made.

In place of a technical session on Thursday morning an Inspection Trip to Radio City has been arranged. Members are invited to assemble at 9:30 a. m. in the Main Building of Radio City at 49th St., between 5th & 6th Aves. where guides will meet them and conduct small groups through the N. B. C. and the British Buildings. An opportunity will be given to see the mechanical equipment and the air conditioning apparatus in service in these two units. The party will be under the direction of W. A. Keplinger. Tickets for this event will be supplied without charge but they should be secured in advance at the registration desk.

On Thursday afternoon the ladies are to have a theater party. They are invited to assemble in the hotel lobby and motor transportation will be provided to the theater. The performance commences at 2:00 p. m.

Tuesday and Thursday evenings have been reserved for the members and ladies to entertain themselves and they will find many diversions on New York's famous White Way.

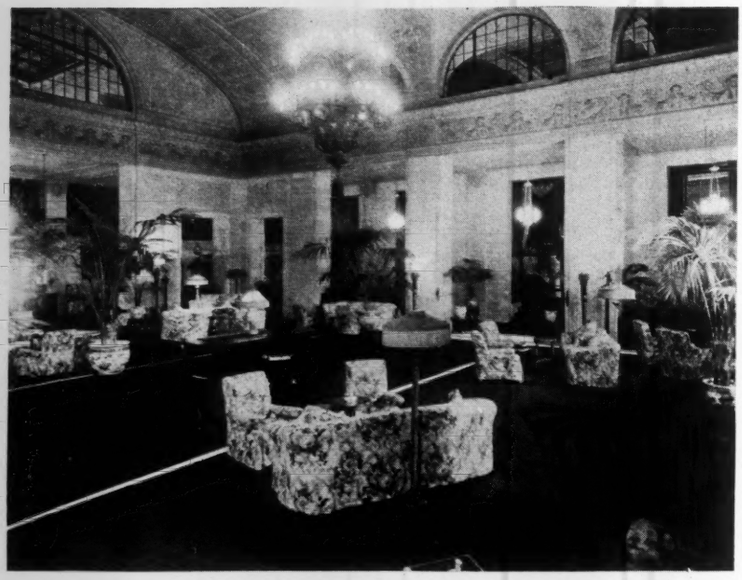
The Committee on Arrangements has set nominal prices for the Monday night party and the annual banquet.

Hotel rates at the Hotel Biltmore range from $4 to $6 single rooms and $7 to $10 double rooms. For less expensive accommodations, Hotel Commodore under the same management, is available; single rooms are priced from $3 to $6; double rooms from $4.50 to $10.

The railroads are cooperating and providing reduced fares under the identification certificate plan, round trip rate being fare and one-third.

Members of the Society will receive in the mail Hotel Reservation Cards, Railroad Certificates and Tickets for the Third International Heating and Ventilating Exposition.

The week of February 5 will be a gala occasion for the members of the A. S. H. V. E. and everyone is urged to come.



The Palm Court, Hotel Biltmore

PROGRAM

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

Hotel Biltmore February 5-8, 1934 New York

Monday, February 5

9:00 a. m. Registration

10:00 a. m. Meeting of the Council

1:00 p. m. Opening of Third International Heating & Ventilating Exposition at Grand Central Palace

FIRST SESSION, Monday, February 5

2:00 p. m. Greeting

Response by Pres. W. T. Jones

Technical papers:

Automatic Controls for Forced Air Heating Systems—Konzo and Hubbard

Corrosion Studies in Steam Heating Systems—Seeber and Rohrman

Heating Buildings with Hot Water—Burt and Lewis

Report of the Council

Report of the Secretary

Amendments to By Laws

Report of Committee on Code for Testing and Rating Condensation and Vacuum Pumps, John Howatt, Chairman

Report of Tellers of Election

8:00 p. m. President's Reception and Get-Together Dinner and Informal Dance, Casino Bleu, Hotel Biltmore

1:00 p. m. to 10:30 p. m. Heating and Ventilating Exposition

SECOND SESSION, Tuesday, February 6

9:30 a. m. Report of Committee on Research, Prof. G. L. Larson, Chairman

Technical Papers:

Construction and Equipment of the Pierce Laboratory—Prof. C.-E. A. Winslow

Selecting Temperatures and Wind Velocities for Calculating Heating Losses, by P. D. Close

Radiation of Energy Through Glass—Blackshaw and Houghten

Studies of Solar Radiation Through Bare and Shaded Windows—Houghten, Gutberlet, and Blackshaw

Report of Finance Committee, John Howatt, Chairman

12:00 noon to 10:30 p. m. Heating and Ventilating Exposition

THIRD SESSION, Tuesday, February 6

2.00 p. m. Report of Guide Publication Committee, W. L. Fleisher, Chairman

Technical papers:

A Proving Home for Air Conditioning Investigations—Elliott Harrington

Low-Cost Air Conditioning for a Small Residence —M. K. Drewry

Comfort Cooling with Attic Ventilating Fans—Helmrich and Tuttle

Study of Summer Cooling in the Research Residence for the Summer of 1933—Kratz and Konzo

2:30 p. m. Ladies' Bridge and Tea

7:00 p. m. Past Presidents' Dinner

12:00 noon to 10:30 p. m. Heating and Ventilating Exposition.

FOURTH SESSION, Wednesday, February 7

9:30 a. m. Report of Membership Committee, E. K. Campbell, Chairman

Technical papers:

Thermodynamic Properties of Moist Air—Prof. J. A. Goff

Study of Air Conditioning and Office Employees Efficiency—McConnell and Kagey

Observations of Hay-Fever Sufferers in Air-Conditioned Room and the Relationship Between the Pollen Content of Outdoor Air and Weather Conditions—Kendall and Weidner

Report of Publication Committee, W. E. Stark, Chairman

12:00 noon to 10:30 p. m. Heating and Ventilating Exposition

FIFTH SESSION, Wednesday, February 7

2:00 p. m. Technical papers:

Diurnal and Seasonal Variations in the Small-Ion Content of Outdoor and Indoor Air—Yaglou and Benjamin

A Biologist Thinks of Air Conditioning—Dr. R. G. Harris

Relationship of Temperature and Humidity to Diseases—Dr. Guy Hinsdale

Air Conditioning in Its Relation to Human Welfare—Dr. C. A. Mills

7:30 p. m. Annual Banquet and Dance, Ballroom, Hotel Biltmore

THURSDAY, February 8

9:30 a. m. Assemble at Radio City for Inspection of Mechanical Equipment in N. B. C. and British Buildings

SIXTH SESSION, Thursday, February 8

1:30 p. m. Ladies' Theater Party

2:00 p. m. Technical papers:

Study of Fuel Burning Rates and Power Requirements of Oil Burners in Relation to Excess Air —Seeley and Tavanlar

Boiler Testing—C. W. Brabbée

Conference on Nomenclature

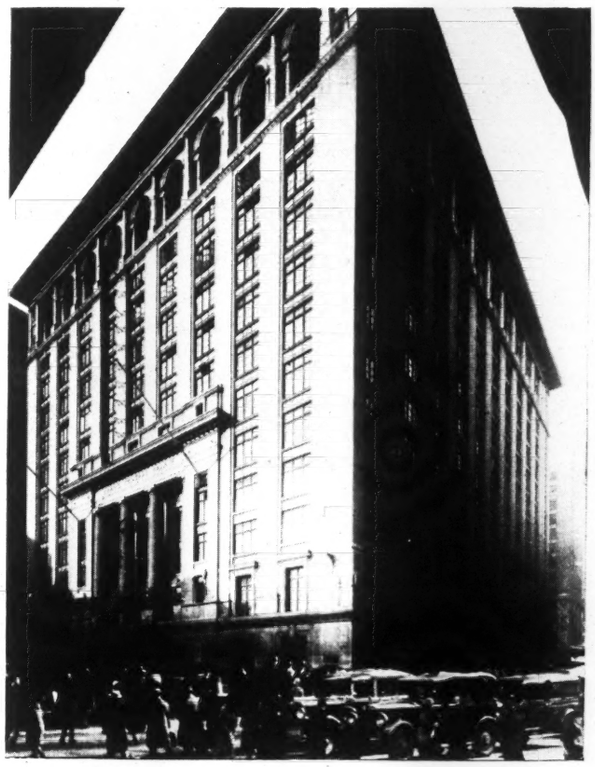
Installation of Officers

Resolutions

Adjournment

4:00 p. m. Organization meeting of the Council

12:00 noon to 10:30 p. m. Heating and Ventilating Exposition, Grand Central Palace



Grand Central Palace

Third Heating and Ventilating Exposition

The major divisions of heating, ventilating, air conditioning, piping and refrigeration will be represented among the exhibits at the Third International Heating and Ventilating Exposition, scheduled for the week of February 5 in Grand Central Palace, New York. Oil and gas burners, warm air furnaces, steam and hot water boilers, electrical heating devices, insulating materials, instruments and specialties will occupy the booths which have been reserved. The trend of business improvement is evident in the preparations being made by exhibitors. Predictions are that this Show will develop a greater interest and more surprises than were evident at the last three expositions which have been held in New York during the past two months.

Judging from the demand for space by leading manufacturers, the scope of exhibits will be of record proportions. Public interest in this great display of comfort equipment is at a high point and people are looking to scientists and engineers to provide their homes, offices, stores, theaters, hospitals, hotels and other places of public assembly with equipment that maintains year-round comfort by automatically cleaning, heating and cooling the air.

It is predicted that the American home of the future will include complete climate control and the home owners will require the architect, the engineer, the builder and equipment manufacturers to produce materials and constructions that will meet the demands of progress. The applications of heating, ventilating and air conditioning are so comprehensive and so necessary for human comfort that a vast market exists and it will be a factor assisting in economic and industrial recovery.

The A. S. H. V. E. exhibit will be devoted largely to the Society's Research activities and will graphically portray the work being carried on at the Research Laboratory in the U. S. Bureau of Mines, Pittsburgh, and in the various cooperating institutions where problems are being sponsored by the Society's Committee on Research. Information on other Society activities will be available and the A. S. H. V. E. GUIDE 1934 will be introduced during the Exposition.

The Third International Heating and Ventilating Exposition will focus the attention of active buyers on the products that have been developed for every heating and ventilating requirement. Don't miss the Exposition!

Michigan

November 13, 1933. The second meeting of the season with 102 members and guests in attendance was held at the Wardell Hotel. First on the program was the entertainment of the evening which consisted of Emory Parnell with his one man band and impersonations.

At this meeting amendments to the constitution and by-laws were unanimously passed and Pres. H. E. Paetz named W. G. Boales as representative and Tom Brown as alternate to represent the Chapter on the Nominating Committee, at the Society's Annual Meeting in New York, February 5-8.

L. L. McConachie, chairman of the Membership Committee, read the following list of new limited chapter members, whose applications had been accepted by the Board of Governors: Frank Marzolf, W. R. Hutton, C. B. Acker, F. L. Nelson, Harold Warr, Peter Eddy and A. E. Knibb.

Milton Powers was the first speaker and was introduced by President Paetz. Mr. Powers explained engineering details of a boiler burner unit and discussed the advantages of cast iron construction and efficient burning rates.

D. J. Luty gave a very interesting detailed description of the proper design required in boiler burner units, covering especially the amount, design and location of heating surface in boiler burner units. In his discussion of the oil burning warm air furnace, he emphasized how much heating surface was available in these units.

The next speaker was Y. R. F. Giddey, who read a very complete description of the specifications of another boiler burner unit using cast-iron fins for additional heat absorption. He explained the diffusion of the upper travel of the gases, which increased the efficiency of the unit.

Some points relative to the early experience of conversion burner sales and their ordinary lack of efficiencies were given by E. S. Jeffries, who also brought out the advantages of the application of induced draft which overcomes difficulties of chimney deficiencies.

President Paetz thanked the speakers for their cooperation and, upon motion by F. R. Bishop, seconded by J. S. Kilner, a rising vote of thanks was given to the speakers.

Richard Hankin Dies

Friends and associates of Richard Hankin, a member of the firm of John Hankin and Brother, consulting engineers, New York, N. Y., will regretfully learn of his death on November 13, 1933 in Passaic General Hospital, after an illness of six months.

Mr. Hankin was born at Farnworth, England, on July 15, 1870, and came to the United States as a young man, studying at Cooper Union. At the beginning of his engineering career he served as a machinist's apprentice at the New York Air Brake Co. at Watertown, N. Y., from 1888 to 1890, and later was connected with Akron Heating & Ventilating Co., Akron, O., Onderdonk Heating & Ventilating Co., Philadelphia, Pa., and Wells & Newton Co. and Frank Dobson, in New York.

Mr. Hankin became a member of the A. S. H. V. E. in 1898 and also belonged to several masonic orders and lodges, also the *American Society of Engineers,* the *New York Professional Engineers,* and the *Building Trades Employers Association Club.*

The Officers and Council feel keenly the loss of a valued member of long standing and express their sympathy to his widow, Mrs. Nina Maltby Hankin, his daughters, Mrs. Sidney A. Riley, Jr. and Mrs. F. Lester Congdon, and his brothers, John and Dr. Walter E. Hankin, who survive.

NOMINATIONS FOR 1934

The Nominating Committee appointed to select candidates for Officers of the Society for the coming year, 1934, submits the following list of nominees:

For President:

C. V. HAYNES, Philadelphia, Pa.

For First Vice-President:

JOHN HOWATT, Chicago, Ill.

For Second Vice-President:

G. L. LARSON, Madison, Wis.

For Treasurer:

D. S. BOYDEN, Boston, Mass.

For Members of the Council:

Three-Year Term

E. H. GURNEY, Toronto, Ont.
W. A. RUSSELL, Kansas City, Mo.
O. W. OTT, Los Angeles, Calif.
M. C. BEMAN, Buffalo, N. Y.

One-Year Term

ALBERT BUENGER, St. Paul, Minn.

Respectfully submitted,

NOMINATING COMMITTEE,

W. R. EICHBERG, *Chairman;*
C. A. PICKETT, *Secretary.*

In accordance with the provisions of the Amended Constitution, as given, ballots containing the names of the above candidates will soon be sent to the membership for voting upon prior to the Annual Meeting in January.

Art. B-VIII—Section 10. The Nominating Committee shall consist of one (1) member eligible to vote designated by each Chapter, or his alternate also appointed by the Chapter. The Secretary of each Chapter shall certify to the Secretary of the Society on or before January first the names of the member and alternate selected.

The Committee shall meet at the Annual Meeting of the Society at the call of the Secretary of the Society and shall effect its own organization and elect its own Chairman. At the Semi-Annual Meeting of the Society, if possible, the Nominating Committee shall select the nominees for the ensuing year for the offices of President, First Vice-President, Second Vice-President, Treasurer, and four (4) members of the Council. In any event the names of the nominees shall be certified to the Secretary of the Society before September twentieth, with the written consent of each nominee to fill the office for which he has been selected and their names with the offices to which they have been nominated shall be published in the October issue of the JOURNAL.

Art. B-IX—Section 2. The Secretary shall prepare ballots with the names of all candidates and forward them to the members, eligible to vote, at least thirty (30) days before the date of the Annual Meeting.

Nominations for Members of Committee on Research

Although committees of the Society are usually appointed, in view of the great importance of the Committee on Research and the financial responsibility it would be called upon to assume, it has been made more representative of the entire membership of the Society by a process of *election.* The election is governed by the By-Laws for the election of officers, with the single exception that Members of the Committee on Research are nominated by the Council instead of by a Nominating Committee.

In accordance with the Regulations for the Government of the Research Laboratory, adopted at the January, 1919, Meeting, and amended January, 1933, the Council announces the nomination of the following members of the Committee for election to succeed those members whose present terms expire January, 1934:

Three-Year Term

C. A. BOOTH, Buffalo, N. Y.
E. K. CAMPBELL, Kansas City, Mo.
JOHN HOWATT, Chicago, Ill.
A. J. NESBITT, Philadelphia, Pa.
J. H. WALKER, Detroit, Mich.

The regulations governing the nomination and election of members of the Committee on Research are as follows:

ARTICLE II—ORGANIZATION

Section 1. *Committee on Research*—There shall be a standing committee known as the Committee on Research, consisting of fifteen (15) members each serving for three (3) years and five (5) retiring each year. The outgoing Chairman if serving in that capacity during the last year of his three (3) year term on the Committee shall without election become an additional member of the Committee on Research for one (1) year.

(a) The Council shall nominate previous to July first of each year five (5) members to fill the vacancies of those retiring at the next Annual Meeting.

(*b*) The nominations made by the Council shall be published in the October issue of the Society's Journal.

(*c*) Any ten (10) members of the Society eligible to vote may present to the Secretary over their signatures, the name of one (1) or more additional nominees for the Committee on Research, provided such name or names are presented at least sixty (60) days prior to the next Annual Meeting, and such additional nominations shall be placed on the ballot opposite the nominations made by the Council.

(*d*) The election shall otherwise conform to the regulations provided for the election of officers of the Society in the Constitution, By-Laws and Rules.

(*e*) Vacancies may be filled by the Council, such persons chosen by the Council to serve until a successor is elected at the next Annual Meeting.

Cleveland

November 20, 1933. The meeting held in the rooms of the *Cleveland Engineering Society* was attended by 21 members and guests and was called to order by Pres. F. A. Kitchen.

The minutes of the October meeting were read and in the treasurer's report, H. M. Nobis discussed the financial status of the Chapter and informed the members that in the future dues would cover the period from January 1 to December 31.

In the absence of the chairman of the Membership Committee, President Kitchen proposed the name of G. B. Longcoy for membership and E. J. Verimere proposed the name of A. L. Vanderhoof. It was moved by Mr. Nobis that these men be accepted as members and the motion was carried.

President Kitchen discussed the question of membership and explained the limited membership plan. Referring to the notice of the meeting, he called attention to the men selected to serve on each membership team and stated that part of their duties would be to help increase the attendance at meetings.

Reference was made to a letter from Secy. A. V. Hutchinson of the Society relative to Chapter representatives on the Nominating Committee. President Kitchen stated that, unless there was some objection, he would reappoint the members who served in this capacity last year: C. F. Eveleth as representative and F. A. Kitchen as alternate. These appointments were approved.

F. C. Houghten, director of the A. S. H. V. E. Research Laboratory, Pittsburgh, Pa., was introduced by President Kitchen and spoke on the subject of Applications of Cooling to Buildings in Summer.

Mr. Houghten's opening remarks dealt with the organization and functions of the Research Laboratory from the time of its origin in 1919 to the present year and the cooperative work conducted at various schools and colleges. He then commented upon the affect of research on engineering practice, mentioning the data in THE GUIDE which have been directly affected by the studies made at the Laboratory.

A brief resumé of the subjects that have been studied by the Committee on Research, namely: factors affecting heat loss from buildings, heat gain, ventilation standards, garage ventilation, dust determinations, and radiation, was followed by a detailed discussion of the work conducted in 1933 relative to heat gain by buildings during the summer. Slides were used to illustrate the effect of various kinds of shades, blinds and awnings on room temperature and cooling load, it being pointed out that direct radiation from the sun is the largest factor affecting heat gain.

Mr. Houghten's talk inspired a great deal of discussion and considerable time was spent in answering questions relating to the lecture. Later Mr. Houghten replied to several queries that members had prepared prior to the meeting.

The new secretary of the Cleveland Chapter, M. B. Wright, states that the meeting was adjourned at 10:05 p. m., after a rising vote of thanks had been extended to Mr. Houghten.

Minnesota

November 7, 1933. The Minnesota Chapter of the Society held its regular meeting at the Men's Union, University of Minnesota, at 6:15 p. m. with 90 members and guests present. At the conclusion of dinner, Pres. A. B. Algren called for the minutes of the October meeting which were read and approved. A. J. Huch outlined a program for a membership drive to take place during the month of November.

A letter from the secretary of the A. S. H. V. E. was read regarding the appointment of two members to represent the Minnesota Chapter on the Nominating Committee. A motion was made by Albert Buenger and seconded that the Executive Committee ascertain who would be present at the Annual Meeting in New York and that the chair appoint the two representatives from this group.

F. D. Berkeley, the speaker, was introduced by G. C. Morgan and gave a very interesting and instructive lecture, illustrated by stereopticon slides, on The History and Application of the Decalorator. A lively discussion took place at the end of the talk and Secy. C. E. Gausman states that the Chapter was very glad to have Mr. Berkeley with them.

New York

November 20, 1933. When the New York Chapter met at the Building Trades Club, 49 members and guests were present for dinner and 55 more attended the meeting.

Pres. H. L. Alt presided and announced the appointment of H. G. Meinke as chairman of the Membership Committee.

Arthur Ritter, chairman of the Committee on Arrangements for the 40th Annual Meeting of the Society, outlined the plans under way for holding this anniversary meeting at the Hotel Biltmore, Feb. 5-8.

W. T. Jones, Boston, Mass., president of the A. S. H. V. E., was a guest of the Chapter and spoke on the Status Quo of the Society. President Jones in a very forceful manner outlined the value of membership and gave interesting statistics regarding the Society's activities and its income and expenditures.

The Significance of Engineering Economy in Hospital Design was the subject of C. F. Neergaard, New York hospital consultant. In a very worthwhile paper, Mr. Neergaard stated that the difficulty with hospital design was due to insufficient consideration of the hospital as an operating unit when plans were being prepared. A building committee would often incorporate all the cherished dreams of dietitians, doctors, and everything they had read about, which would seem to be the last word in hospital design, but which would prove to be inefficient in operation. For example, a committee would spend only a few minutes on a $100,000 expenditure for new equipment and hours discussing the selection of hardware.

Various members joined in the discussion which followed and S. L. Butler, president of the Hospital Council of the City of New York and responsible for 81 hospitals, was called upon for his comments. Mr. Butler complimented Mr. Neergaard on his understanding of the operation and design of hospitals and the amount of detail which had been brought out in his paper, and said that there was no field in which greater savings were possible.

Dr. C. W. Brabbée stressed the advisability of the appointment of an engineer on the hospital board with the authority and means to provide that the budget would take care of the operation and design.

In closing the discussion, Mr. Neergaard said that there was no definite useful life of mechanical equipment in hospitals as they were wont to continue with obsolete equipment due to shortage of funds. Mr. Neergaard urged engineers to take a more aggressive stand when retained in hospital work and suggested a control board sponsored by the A. S. H. V. E. to establish standards for economic hospital planning.

Southern California

November 14, 1933. The November meeting was featured by a dual program, with C. S. Anderson first presenting a paper on Steam Refrigeration and illustrating his talk with slides. The subject was very capably presented and was discussed thoroughly by those present.

E. B. Rider showed a motion picture of the development work

along the Metropolitan Aqueduct, the $50,000,000 water project now being constructed in Southern California.

The election of officers for the new year was held with the nominations presented by the committee being unanimously elected as follows:

President—W. H. C. Ness.
Vice-President—W. E. Barnum.
Secretary—E. H. Kendall.
Treasurer—H. L. Warren.
Board of Governors—L. H. Polderman, W. E. Cranston, H. H. Douglas, A. H. Simonds.

The meeting was attended by 55 members and guests and, according to the report of Secretary Kendall, was adjourned at the very late hour of 2:35 p. m.

Philadelphia

November 9, 1933. Pres. M. F. Blankin called the members and guests of the Philadelphia Chapter to order at the Engineers Club, when the minutes of the previous meeting and the treasurer's report were read and approved.

H. G. Black, chairman of the Technical Service Committee, stated that approximately one-third of the quota for this fund had been collected with a number of the committee still to be heard from.

The Nominating Committee reported the following slate for Officers and Board of Governors for 1934:

President—W. P. Culbert
Vice-President—J. H. Hucker
Secretary—W. R. Eichberg
Treasurer—W. F. Smith
Board of Governors—M. F. Blankin, A. C. Caldwell, Alexander McClintock, Jr.

Mr. McClintock, chairman of the Membership Committee, introduced two new members to the Chapter, T. J. Adkins and R. D. Touton.

The meeting was then turned over to W. F. Smith, chairman of the Meetings Committee, and adjourned to the new W. C. A. U. Broadcasting Building for inspection of the air conditioning and mechanical equipment.

C. S. Leopold, consulting engineer, conducted the Chapter members through the building and explained the equipment in detail. A most enjoyable and interesting time was had by everyone according to the report of Secretary Eichberg.

Pittsburgh

November 13, 1933. Forty-four members and guests were present when Pres. G. S. McEllroy called the meeting to order in the auditorium of the U. S. Bureau of Mines at 7:40 p. m.

The minutes of the October meeting were read and approved and H. B. Orr, treasurer, presented his report, which was ordered filed.

L. B. Pittock, chairman of the Program-Publicity Committee, announced that the next meeting of the Chapter would be its annual meeting for the election of officers and that because of certain changes scheduled to take place in the country's Constitution, an informal smoker would be arranged instead of a formal talk.

The chairman of the 1934 Nominating Committee, F. C. McIntosh, submitted the following report of nominations to be voted upon at the December meeting:

President—P. A. Edwards
Vice-President—L. B. Pittock
Secretary—J. L. Blackshaw
Treasurer—H. A. Beighel
Board of Governors—F. H. Hecht, G. S. McEllroy, R. J. J. Tennant.

An appeal for new members for the A. S. H. V. E. and the Pittsburgh Chapter was made by President McEllroy, who also requested that members pay current and delinquent Chapter and Society dues to enable the Society to carry on its work in research, education, and organization.

President McEllroy presented the Chapter's guest and speaker, C. T. Ingham, Pittsburgh architect, who spoke on The Architect and the Salesman. Mr. Ingham discussed the many types of salesmen he constantly meets and their various abilities to aid, hinder, educate or confuse a man at his work. According to the speaker, unfortunately, when an architect has plenty of time to talk, salesmen are seldom around, but at the moment he is busiest on a job, he is deluged with salesmen and their wares and schemes. Mr. Ingham announced that if they would remember this and act accordingly, they would usually be welcomed.

Mr. Ingham classified salesmen into the following five groups:

1. The experienced and capable man who ably represents good products, makes few enemies, and keeps his friends.
2. The glad-hand, back-slapping type that shows up only when local contracting magazines announce a new job.
3. The young man learning the game who knows only a phonograph-like talk his company has had him memorize.
4. The man who displays his samples but is merely an order taker and has to get his company to answer all questions.
5. The men who shows up one year representing product *A* at the expense of product *B* and comes back next year boosting *B* against *A*.

After a lengthy and enjoyable discussion, during which the subject of free engineering was talked over, Mr. Ingham was given a rising vote of thanks.

Western Michigan

December 11, 1933. The December meeting of the Western Michigan Chapter was held in Kalamazoo, Mich., in place of its usual assembly at Grand Rapids. Since a large portion of the Chapter's membership comes from centers other than Grand Rapids, it is intended to hold at least one meeting a year in a neighboring city in Western Michigan, hoping that this will act as a stimulus to membership throughout the entire Chapter area. The response to this meeting showed an unprecedented interest by an attendance of 68 at dinner and 80 at the engineering session.

Following a short business session and introduction of guests, the meeting adjourned to the factory of Clarage Fan Co., where a demonstration was given of dynamically balancing a multiblade blower wheel.

S. H. Downs, chief engineer, gave a very complete explanation of the development of vortex volume control and constant velocity register face. A laboratory set up of a wind tunnel with these devices applied demonstrated their action and characteristics. A complete air conditioning system was in operation providing optimum conditions for year round service to an isolated room, using city tap water at a maximum of 56 deg as the cooling agent.

The members of the Chapter wish to commend their hosts for their contribution to a better understanding of air handling equipment.

November 14, 1933. After dinner and a business meeting held at the Rowe Hotel, Grand Rapids, the program was turned over to W. G. Boales, of the Michigan Chapter, who had arranged for the speakers.

The subject for discussion was Oil Burner Boiler Units and new developments in this field were ably explained by M. A Powers and R. E. Van Norstrand. In summary of the talks and discussion which followed, it appears that to reach higher efficiencies and more satisfactory operation of domestic oil burning boilers, the burner and the boiler should be coordinated so that their peak efficiencies and desirable characteristics intersect at the same point in their operating ranges.

Since this was a popular subject, interested guests swelled the attendance of the meeting to 56.

Illinois

December 11, 1933. The Meetings and Membership Committees of the Illinois Chapter are to be congratulated on the fine attendance of 89 members and guests, who were present at the

Hotel Sherman. Pres. C. W. DeLand called the meeting to order at 7:40 p. m.

R. E. Hattis, vice-president and chairman of the Membership Committee, told of the good work of his committee and announced the receipt of Chapter membership applications from O. W. Armspach, J. H. McIlvaine and F. C. Wood. Applications for membership in the Society have also been obtained from C. J. Lamb and G. G. Turner.

President DeLand outlined the plans for the January meeting, when a visit to the Museum of Science and Industry, founded by Julius Rosenwald, will be followed by dinner at the Windermere Hotel and a talk by a speaker from the Museum.

S. I. Rottmayer, chairman of the Meetings Committee, announced that in February W. W. Reece would speak on Bakery Air Conditioning. This is to be a joint meeting with the Chicago Section of the *American Society of Refrigerating Engineers* and the *American Baking Institute*.

President DeLand suggested to the members who are in arrears in dues that small installment payments would be gladly accepted, and called attention to the appointment of Homer Linn as employment contact man.

The selection of members for the Society's Nominating Committee was the next matter of business. President DeLand was given the privilege of appointing these members and chose J. J. Aeberly as representative and J. J. Hayes, as alternate.

A suggestion made by Meyer Factor that all heating and ventilating plans be approved by the A. S. H. V. E. was referred to the Better Relations Committee.

Mr. Hattis then introduced the speaker of the evening, H. E. Bates, assistant chief engineer of the People's Gas Light and Coke Co., whose subject was Supplying Gas to the City of Chicago.

Mr. Bates gave a very comprehensive talk covering the manufacture and distribution of gas and the piping of buildings for its utilization. He touched upon the large investment of the gas company to take care of peak loads and gave a definition of the gas under discussion, mentioning seven commercial hydrocarbons. He described a desirable gas as one high in heat value and low in specific gravity and non-combustible constituents.

A description of four types of gas producers and details of their manufacture was given by Mr. Bates, who also spoke of the apparatus for mixing natural gas with manufactured gas and outlined three types of distributing systems in use today: the low pressure, medium pressure and high pressure system. A description of Chicago's medium pressure distributing system with cross lines to various points was of interest to every listener.

The talk was concluded with such details as gas holder design, customer's piping requirements, and general capacity statistics of the local gas company. Secretary Hayes states that Mr. Bates' excellent paper was thoroughly enjoyed by all.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Membership Committee as soon as possible.

When the Membership Committee has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 17 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some members by January 15, 1934, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
BETLEM, HENRIETTA T., Betlem Htg. Co., Rochester, N. Y.	Margaret Ingels	Thornton Lewis
	V. S. Day	R. T. Coe
BOCK, I. I., Sales Engr., Carrier Engrg. Corp., Dallas, Tex.	G. H. Meffert	E. P. Renouf
	T. M. Cunningham	L. L. Landauer
BOUCHERLE, HENRY N., Secy., The Scholl-Choffin Co., Youngstown, O.	C. C. Choffin	R. B. Stanger
	F. C. McIntosh	F. H. Hecht
CHARLET, LOUIS W., Br. Mgr., Kewanee Boiler Corp., New York, N. Y.	B. H. Schulze	H. L. Alt
	W. M. Heebner	C. E. Bronson
CURTIS, HERBERT F., Htg. & Vtg. Engr., Henry Furnace & Foundry Co., Cleveland, O.	J. C. Miles	F. A. Kitchen
	R. G. Davis	M. F. Rather
FAILE, E. H., Consulting Engr., E. H. Faile Co., New York, N. Y.	A. P. Keasbey (*A.S.R.E.*)	E. E. Seelye (*A.S.C.E.*)
	C. S. Landers (*A.S.C.E.*)	J. S. Tilley (*A.S.M.E.*)
GRAY, EARLE W., Power Sales Engr., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.	R. G. Dolan	G. H. Meffert
	F. X. Loeffler	E. P. Renouf
HUNT, NOEL P., Managing Director, Carrier Australasia Ltd., Sydney, Australia.	J. R. Duncan	A. E. Stacey, Jr.
	W. H. Carrier	L. L. Lewis
LAMB, CHARLES G., Pres., F. W. Lamb Co., Chicago, Ill.	J. J. Hayes	C. W. Johnson
	H. M. Hart	J. J. Haines
LANGE, FRED F., Engr., Mechanical Service Co., Minneapolis, Minn.	G. C. Morgan	H. E. Gerrish
	Albert Buenger	A. J. Huch
PELOUZE, HENRY L., 2nd, Br. Mgr., C. A. Dunham Co., Richmond, Va.	E. K. Campbell	J. A. Johnston
	E. K. Campbell, Jr.	W. E. Carle